Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-74

Gregory N. Katnik, Barry C. Bowen, Jill D. Lin

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

Photo 1 : Launch of Shuttle Mission STS-74

1.0 SUMMARY

A pre-launch debris inspection of the pad and Shuttle vehicle was performed on 10 November 1995. The detailed walkdown of Launch Pad 39A and MLP-2 also included the primary flight elements OV-104 Atlantis (15th flight), ET-74 (LWT 67), and BI-076 SRB's. There were no significant vehicle or facility anomalies.

A launch attempt was scrubbed 11 November 1995 at T-5 minutes due to the unacceptable weather at TAL sites. A post drain inspection of the vehicle revealed no significant anomalies.

The vehicle was cryoloaded for flight on 12 November 1995. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. There were no ice/frost conditions or protuberance icing conditions outside of the established data base.

After the 7:30 a.m. (local) launch on 12 November 1995, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. There was no visual indication of a stud hang-up on any of the south holddown posts. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal.

A total of 124 films and videos were analyzed as part of the post mission data review. No vehicle damage or missing flight hardware was observed that would have affected the mission. SSME ignition appeared normal. A flare was observed in the SSME #2/#3 plume. The flare was caused by the vaporization of a light-colored object, which first appeared from an area aft of the vehicle and behind the RH SRB plume.

Orbiter umbilical camera films showed nominal separation of SRB's from the External Tank and normal separation of the ET from the Orbiter. Generally, the ET was in good condition. A 3-inch diameter shallow divot was observed at the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant adjacent to the PAL ramp and a shallow, 2-inch diameter divot was observed on the +Y aft fairing closeout.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The number of MSA-2 debonds on the RH and LH frustum was average. The LH frustum exhibited a 2-inch diameter divot with sooted substrate between the BSM cluster and the +Y axis near the XB-275 ring frame and ten MSA-2 acreage debonds.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-104 was conducted 20 November 1995 on SLF runway 33 at the Kennedy Space Center. The Orbiter TPS sustained a total of 116 hits, of which 21 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of hits was less than average and the number of hits 1-inch or larger was average. The Orbiter lower surface sustained a total of 78 hits, of which 17 had a major dimension of 1-inch or larger.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the facility environment, SRB BSM exhaust, Orbiter RCS nozzle cover adhesive, SRB sealant, Orbiter TPS, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of the noted materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of 5 Post Launch Anomalies, but no In-Flight Anomalies (IFA's), were observed during the STS-74 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 9 November 1995 at 1430 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC Shuttle Ice/Debris Systems
J. Lin	NASA - KSC Shuttle Ice/Debris Systems
B. Davis	NASA - KSC Digital Imaging Systems
R. Speece	NASA - KSC Thermal Protection Systems
B. Bowen	NASA - KSC Infrared Scanning Systems
J. Rivera	NASA - KSC ET Mechanisms/Structures
M. Bassignani	NASA - KSC ET Mechanisms, Structures
M. Valdivia	LMSO - SPC Supervisor, ET/SRB Mechanical Systems
R. Seale	LMSO - SPC ET Mechanical Systems
J. Blue	LMSO - SPC ET Mechanical Systems
W. Richards	LMSO - SPC ET Mechanical Systems
M. Wollam	LMSO - SPC ET Mechanical Systems
G. Fales	LMSO - SPC ET Mechanical Systems
Z. Byrns	NASA - KSC Level II Integration
W. Atkinson	Rockwell LSS Systems Integration
M. Nowling	THIO - LSS SRM Processing
J. Ramirez	LMSO - LSS ET Processing
K. Ely	LMSO - LSS ET Processing
D. Maxwell	LMSO - SPC Safety

3.0 LAUNCH

STS-74 was launched at 12:30:43.013 GMT (07:30:43 a.m. local) on 12 November 1995.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 10 November 1995, from 0830 to 1000 hours. The detailed walkdown of Pad 39A and MLP-2 also included the primary flight elements OV-104 Atlantis (15th flight), ET-74 (LWT 67), and BI-076 SRB's. There were no vehicle or facility anomalies.

3.2 WEATHER SCRUB

The Final Inspection of the cryoloaded vehicle was performed on 11 November 1995 from 0140 to 0310 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. There were no ice/frost conditions or protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle.

The launch attempt on 11 November 1995 was scrubbed at T-5 minutes due to unacceptable weather at TAL sites. Pad access was available soon after the scrub and the post drain inspection of the vehicle was performed at Pad-39A from 1245 to 1415 hours on 11 November 1995.

No anomalies (divots or cracks) were observed on the LO2 tank, intertank or LH2 tank acreage.

Inspection of the nose cone -Y side revealed no areas of missing topcoat. The +Y side was not accessible for inspection. An inspection of the vent hood seals revealed no topcoat adhered to either of the seal interfaces, though video data indicates an area of missing topcoat directly below Xt-371 on the LO2 tank ogive, +Z side of the northeast louver. An IPR was taken to document this anomaly (IPR 074V-0134).

Ice/frost in the LO2 feedline bellows and support brackets was mostly melted. Some ice was visible in the two aft-most support brackets. No loose foam or TPS cracks were visible.

The bipod jack pad closeouts were intact and flush with adjacent LH2 tank-to-intertank flange closeout foam.

The 14-inch crack in the -Y ET/SRB vertical strut cable tray forward surface TPS, observed during cryoload, was not visible .

Typical ice/frost formations remained on the ET/ORB LO2 and LH2 umbilicals.

There were no anomalies on the Orbiter, Solid Rocket Boosters, or MLP.

No significant vehicle damage was observed during the post drain inspection that would have been a constraint to the next cryoload.

Launch was rescheduled for 12 November 1995.

3.3 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 12 November 1995 from 0245 to 0410 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. There were no ice/frost conditions or protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle.

3.3.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. F3L and R4D RCS Thruster covers were tinted green indicating a small internal vapor leak. Typical ice/frost accumulations and condensate were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.3.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers averaged 71-76 degrees F. Temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 70-77 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by THIO was 75 degrees F, which was within the required range of 44-86 degrees F.

3.3.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies..

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost accumulation, was present on the acreage.

There were no anomalies on the new-method bipod jack pad closeouts.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, consisted of four OTV recorded items.

3.3.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals.

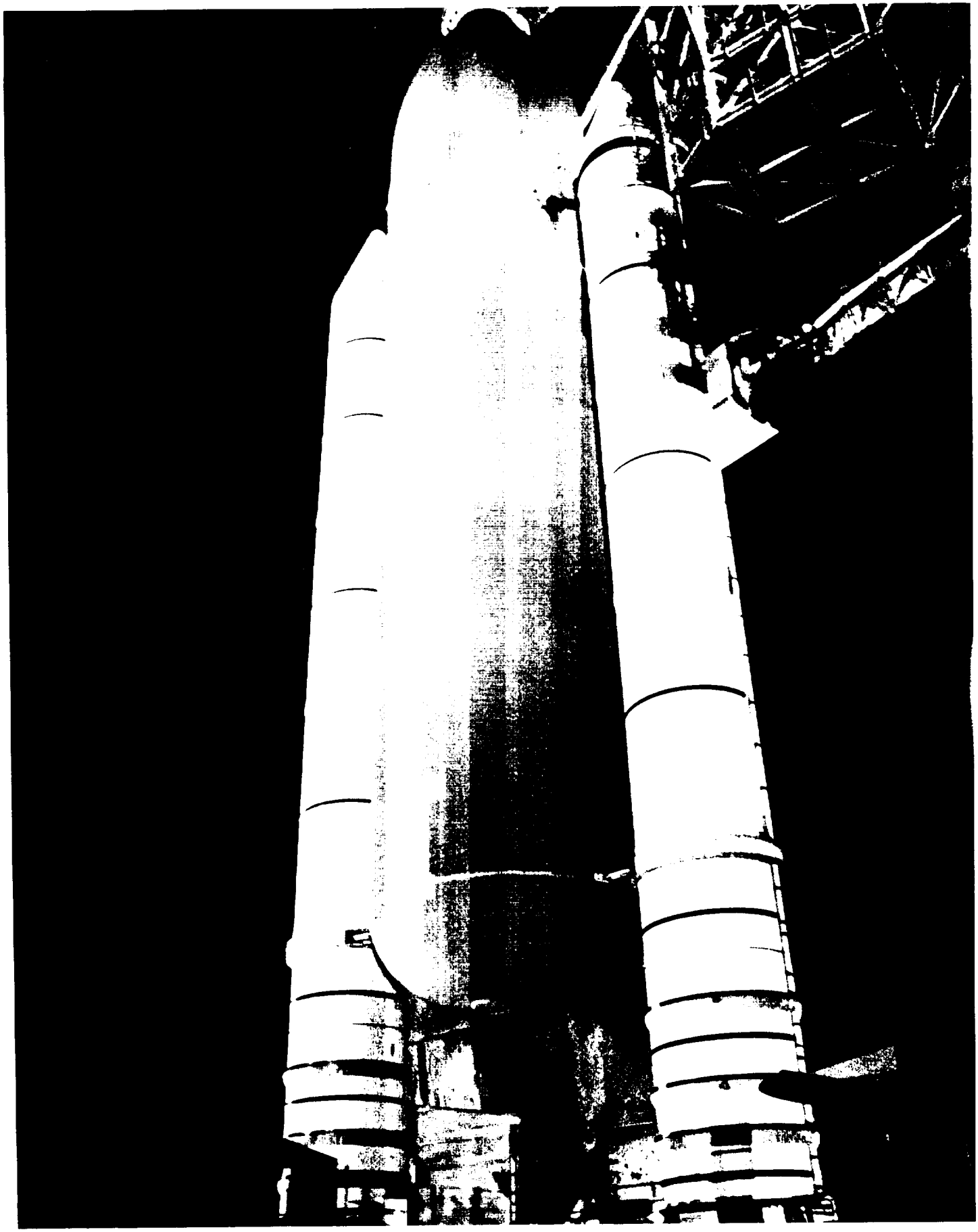


Photo 2 : Cryoloaded External Tank

No acreage ice/frost conditions or TPS anomalies

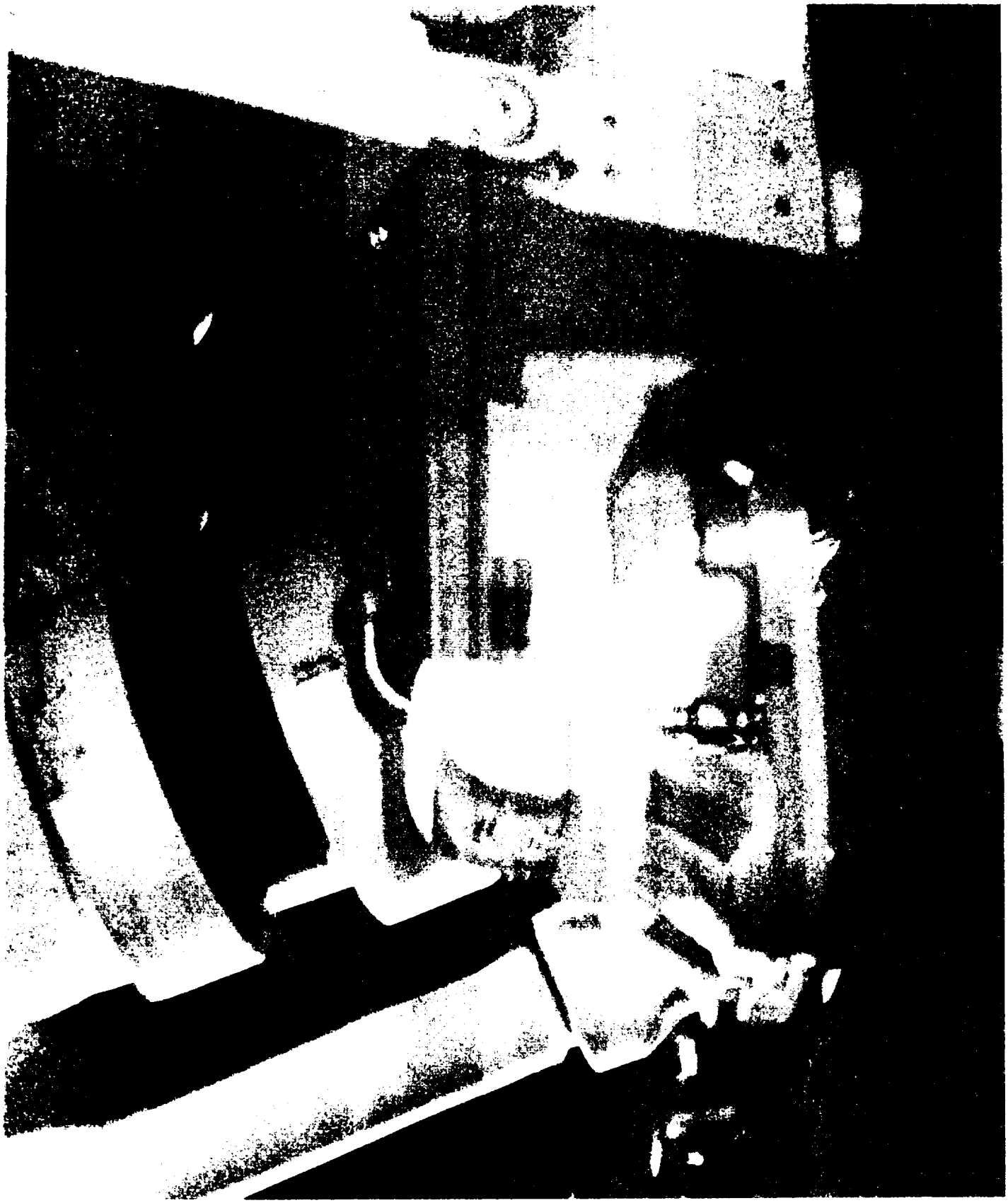


Photo 3 : LH2 ET/ORB Umbilical

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, RSS, and Pad A was conducted on 12 November 1995 from Launch + 1 to 3 hours. The SRB flame trench and pad acreage north of the pad apron were not accessible for inspection due to a facility LH2 leak and LO2 boiloff.

No flight hardware or TPS materials were found.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. Rockwell-Downey reported a 0.10g lateral acceleration at liftoff and no stud hang-ups were expected. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was minimal with some minor corner erosion on HDP #7 blast cover. Minor damage to the SRB aft skirt purge lines and T-0 umbilicals was similar to previous launches.

The Tail Service masts (TSM), Orbiter Access Arm (OAA), and GOX vent hood appeared undamaged. One small area of topcoat, approximately 1/4 inch by 1/2 inch, from the External Tank nose cone (approximate 371 station) adhered to the outboard surface of the +Y (northeast) GOX vent seal.

The GH2 vent line had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound. The GUCP legs and crossbeam showed no obvious signs of contact by the static retract lanyard. The vent line was latched on the seventh tooth of the latching mechanism. The RSS cable had disconnected properly.

FSS damage was much less than normal, probably due to a strong easterly wind. However, several pieces of debris were found in the SSME flame trench. These included:

- 18-inch x 60-inch piece of wire mesh
- Blue evacuation sign
- Several metal clips used to secure metal decking

Overall, damage to the pad appeared minimal.

Post launch anomalies are listed in Section 9.

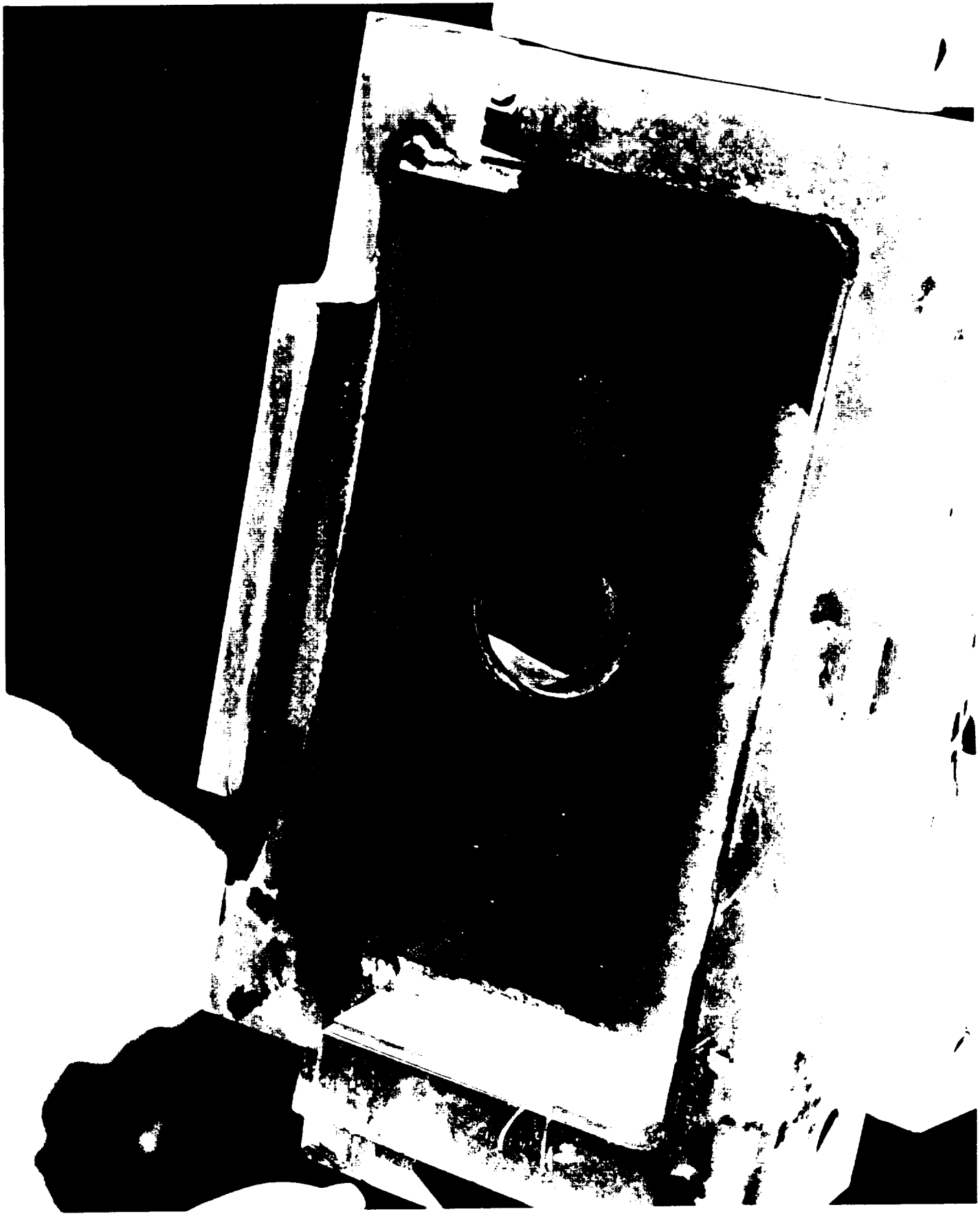


Photo 4 : SRB Hold Down Post Shim

Although the aft skirt shoe shim material was intact, the new material, which is somewhat darker than the material used prior to BI-074, exhibited a bubbled appearance after launch.

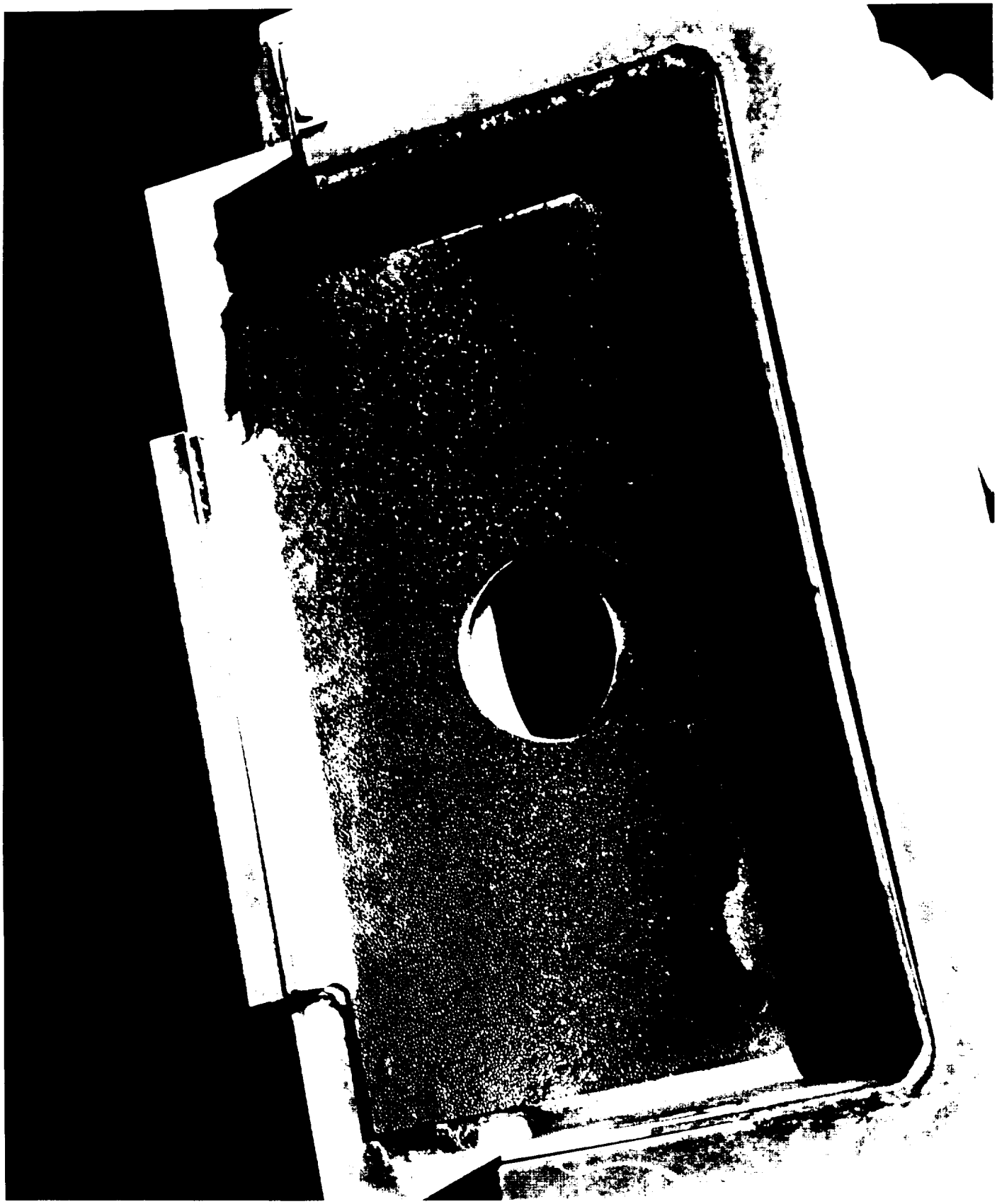


Photo 5 : SRB Hold Down Post Shim

Although the aft skirt shoe shim material was intact, the new material, which is somewhat darker than the material used prior to BI-074, exhibited a bubbled appearance after launch. The aft skirt shoe shim is slightly debonded.

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review. Post flight anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 100 films and videos, which included thirty-nine 16mm films, nineteen 35mm films, five 70mm films, and 37 videos, were reviewed starting on launch day.

SSME ignition and Mach diamond formation appeared normal. Fore-and-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster occurred during engine start-up. The motion was similar to that observed on previous launches (E-76). Free burning hydrogen had drifted upward to the base heat shield and OMS pods during start-up. One igniter spark contacted the SSME #1 nozzle near the exit plane, but no damage was observed (OTV 051, 070, 071). Small pieces of tile surface coating material were lost from 3 places on the base of the RH RCS stinger (E-17), 1 place on the base of the LH RCS stinger (E-20), 5 places on the base heat shield outboard of SSME #2 (E-18), and 5 places on the body flap upper surface outboard of SSME #3 (E-19; OTV 070).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 050, 070, 071). GUCP disconnect from the ET was nominal. No damaged foam was visible in the area after retraction (E-33). Frost on the adjacent TPS was expected (OTV 004).

GH2 vent line retraction and latch were normal. Slack in the static retract lanyard was minimal (E-41, -50, -60).

Debris particles, most likely pieces of SRB throat plug material, and numerous pieces of shredded SRB sound suppression water trough material, were ejected out of the SRB exhaust holes and passed by the SRB aft skirts moving away from the vehicle shortly after T-0.

There were no visible anomalies on the ET nose cone, louvers, and fairing. Two small areas of topcoat were missing from the ET nosecone near the northeast louver at Xt-371. This condition was acceptable for launch. (OTV 013, 060, 062; E-79).

Ice particles from the LO2 feedline bellows fell aft during SSME ignition, but no contact with Orbiter tiles was observed (E-5, -6, -31).

No stud hang-ups occurred on any of the holddown posts. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes.

One piece of light-colored debris, most likely a chunk of instafoam from the RH SRB aft skirt, fell out of the SRB plume after the roll maneuver at 12:30:57.319 GMT (E-57). Another similar particle dropped out of the RH SRB plume later in flight (E-223).

A flare in the SSME #2/#3 plume was caused by the vaporization of a light-colored object, which first appeared from an area aft of the vehicle and behind the RH SRB plume (E-223, frame 4365).

SRB separation appeared nominal (E-212, -220).

In general, most of the long range tracking films were degraded by cloud cover, haze, underexposure, and indistinct images.

Photo 6 : Flare in SSME Plume

Photo 7 : Flare in SSME Plume

A flare in the SSME #2/#3 plume was caused by the vaporization of a light-colored object, which first appeared from an area aft of the vehicle and behind the RH SRB plume.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-104 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. The 16mm camera with 10mm lens did not run.

No vehicle damage or lost flight hardware was observed that would have been a safety of flight concern.

SRB separation from the External Tank was nominal.

ET-74 separation from the Orbiter was nominal. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, PAL ramps, and LO2 feedline. Likewise, no acreage TPS anomalies were detected on the LO2 tank, intertank, and LH2 barrel.

Both new-method bipod jack pad closeouts were intact.

The LH2 tank acreage was generally in good condition with the exception of one 3-inch diameter shallow divot at the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant adjacent to the PAL ramp. Less than usual shallow "popcorn" type divots occurred forward of the crossbeam.

LO2 feedline flange closeouts, thrust strut flange closeouts, and the TPS on several pressurization line supports exhibited minor erosion. Ice was still present in the LO2 feedline lower bellows.

A shallow, 2-inch diameter divot was observed on the +Y aft fairing closeout.

The LH2 ET/ORB umbilical appeared to be in good condition with little or no TPS damage. Foam was missing or eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut. The separation bolt protruded from the EO-2 fitting such that a few threads were visible, but the condition was not considered anomalous.

The LO2 ET/ORB umbilical TPS appeared undamaged. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. All of the lightning contact strips were present and intact.

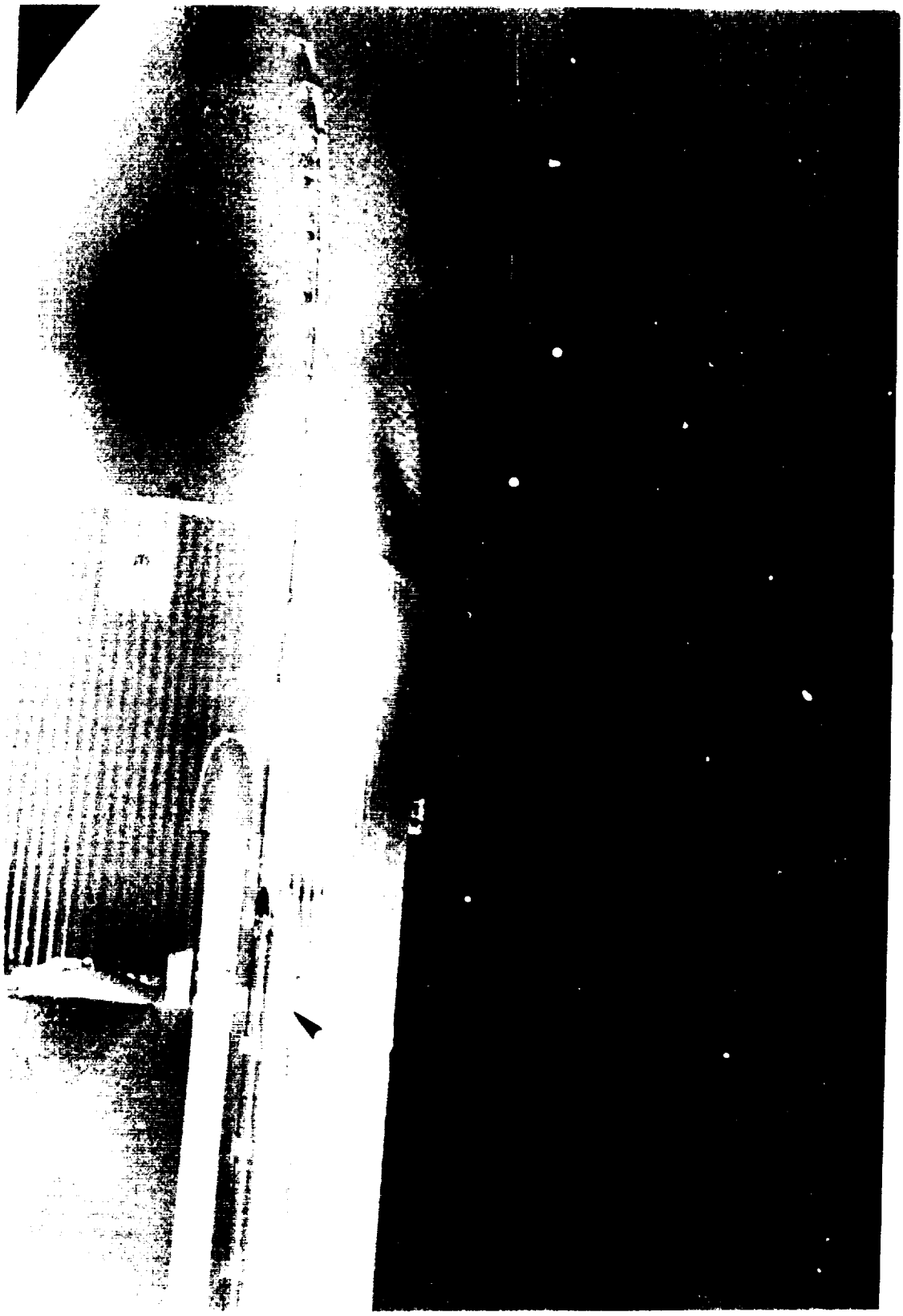


Photo 8: Upper ET After ET Separation

ET-74 separation from the Orbiter was nominal. Both new-method bipod jack pad closeouts were intact. No anomalies were observed on the nosecone, PAL ramps, and LO2 feedline. Likewise, no acreage TPS anomalies were detected on the LO2 tank, intertank, and LH2 barrel. A 3-inch diameter shallow divot was observed at the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant adjacent to the PAL ramp (1).

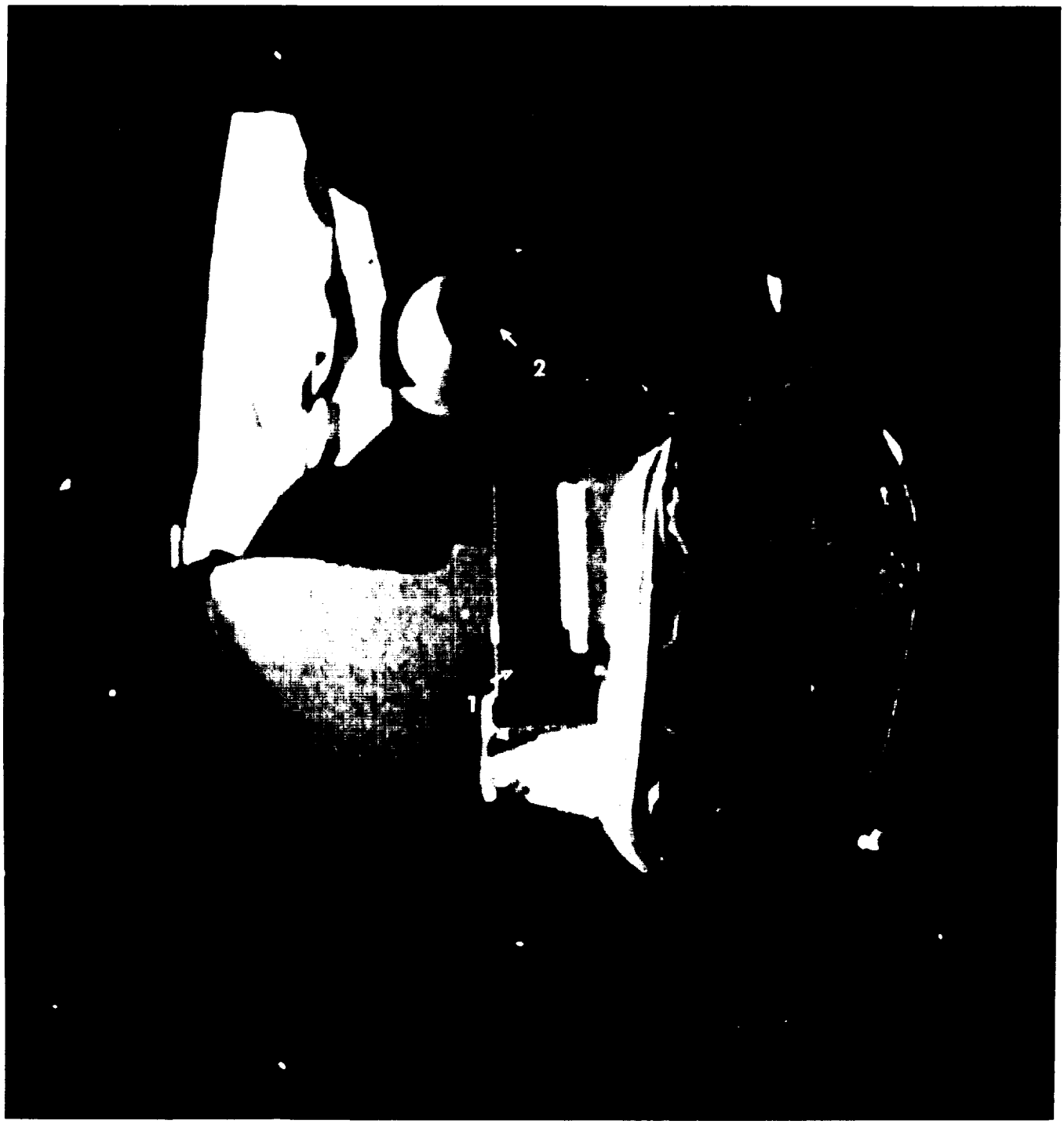


Photo 9: LH2 ET/ORB Umbilical After ET Separation

Foam was missing or eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut (1). The separation bolt protruded from the EO-2 fitting such that a few threads were visible, but the condition was not considered anomalous (2).

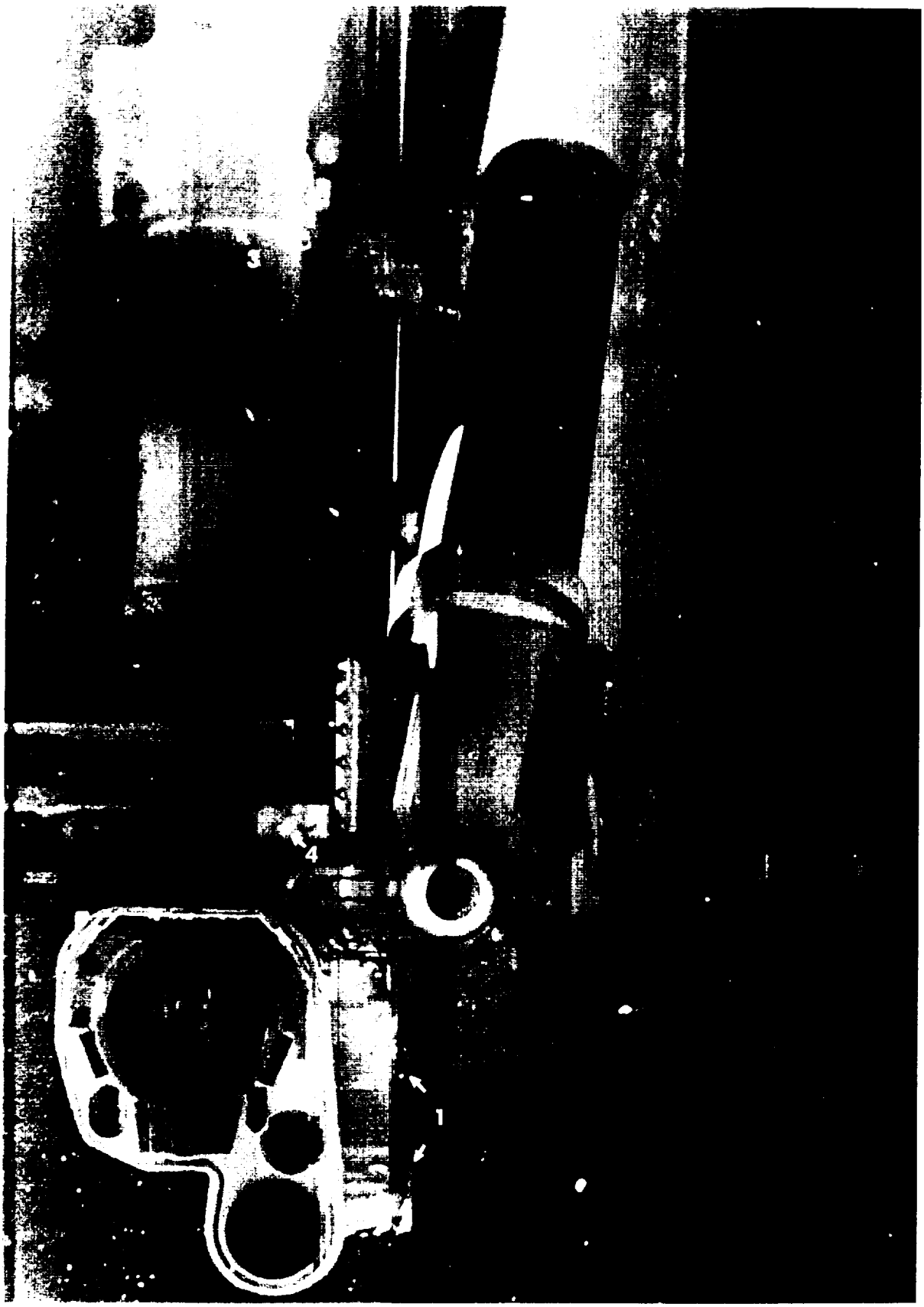


Photo 10: LO2 ET/ORB Umbilical After ET Separation

Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray (1). The LO2 feedline flange TPS closeout exhibited minor erosion (2). Ice was still present in the LO2 feedline lower bellows (3). A shallow, 2-inch diameter divot was observed on the +Y aft fairing closeout (4).

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 21 films and videos, which included two 16mm high speed films, nine 35mm large format films and 10 videos, were reviewed.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. Wing tip vortices on final approach were visible due to the amount of moisture in the air at the time of landing.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. The right main landing gear touched down slightly ahead of the left main landing gear.

Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth.

No significant TPS damage was visible during rollout with the exception of three small areas on the lower surface. Rollout and wheel stop were uneventful.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-076 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 14-15 November 1995. From a debris standpoint, both SRB's were in good condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS. The number of MSA-2 debonds (45) over fasteners was average (Figure 1). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position though the upper right cover attach ring had been bent by parachute riser entanglement. Fibers from the risers were still caught in the cover latch.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact though the +Z plate was delaminated. No pins or retainer clips from the frustrum severance ring were missing or damaged.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ETA ring, IEA, and IEA covers appeared undamaged. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. The HDP Debris Containment System (DCS) plungers appeared to have functioned properly.

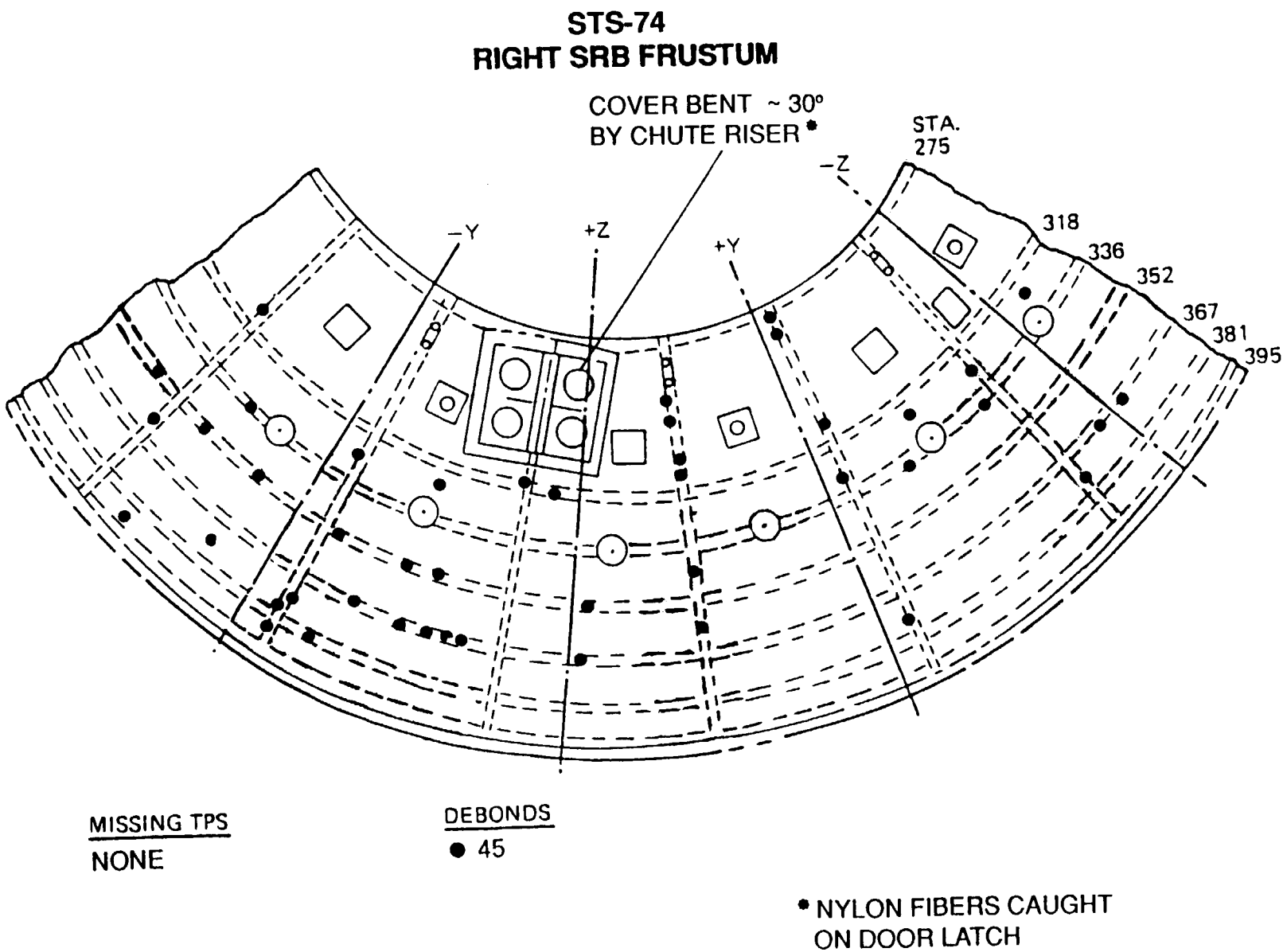


Figure 1 : RH Frustum

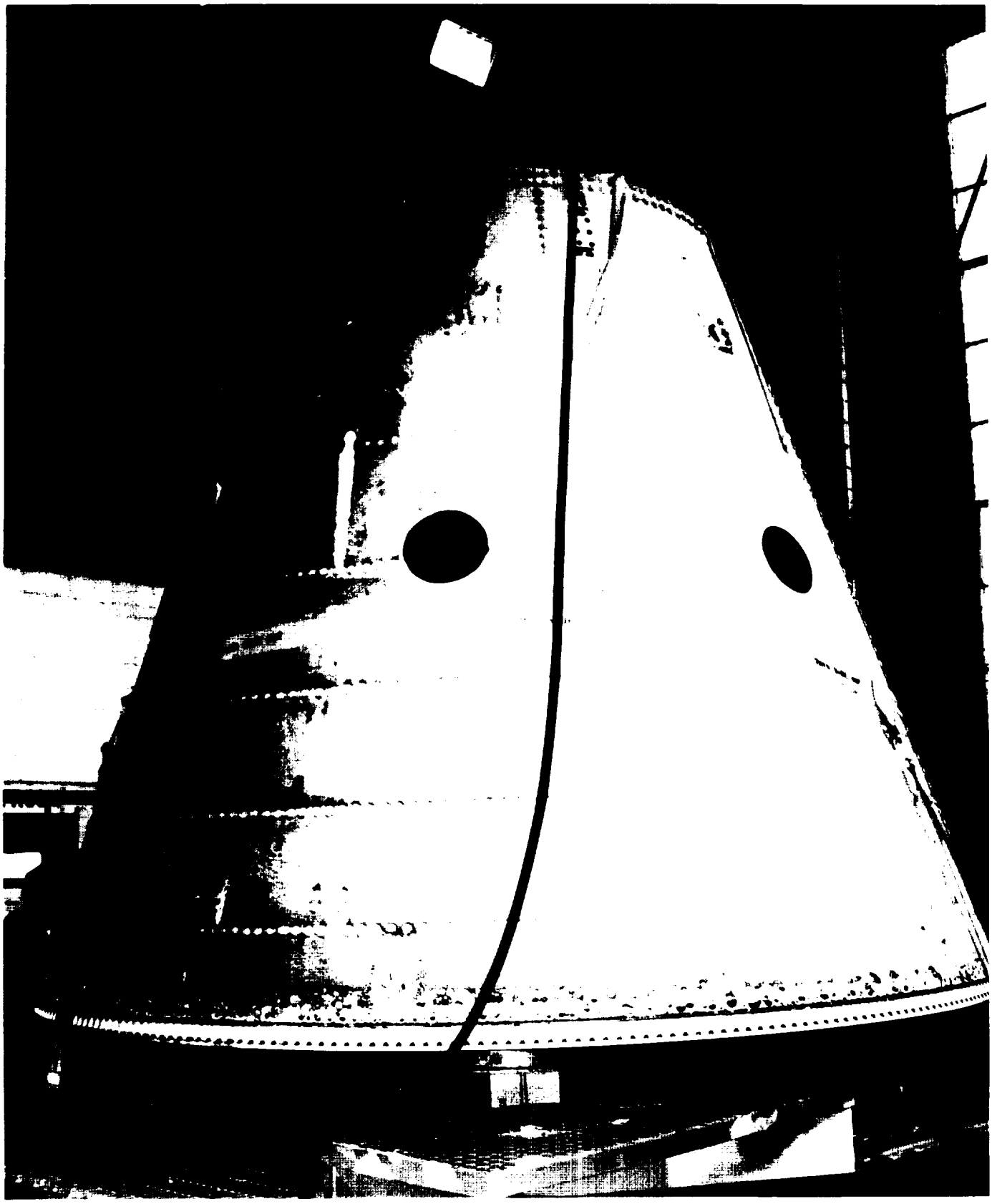


Photo 11: RH Frustrum

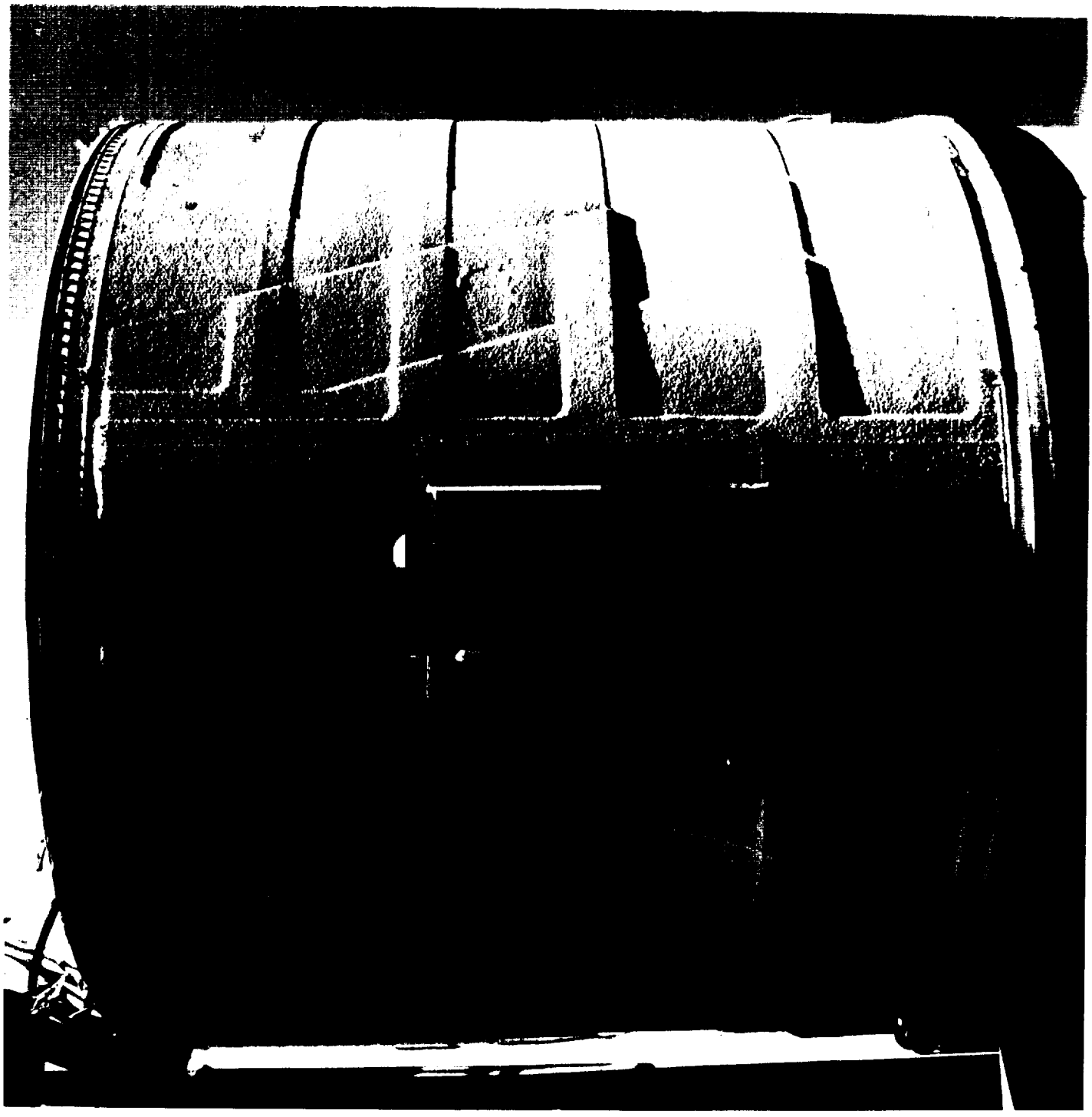


Photo 12: RH Forward Skirt

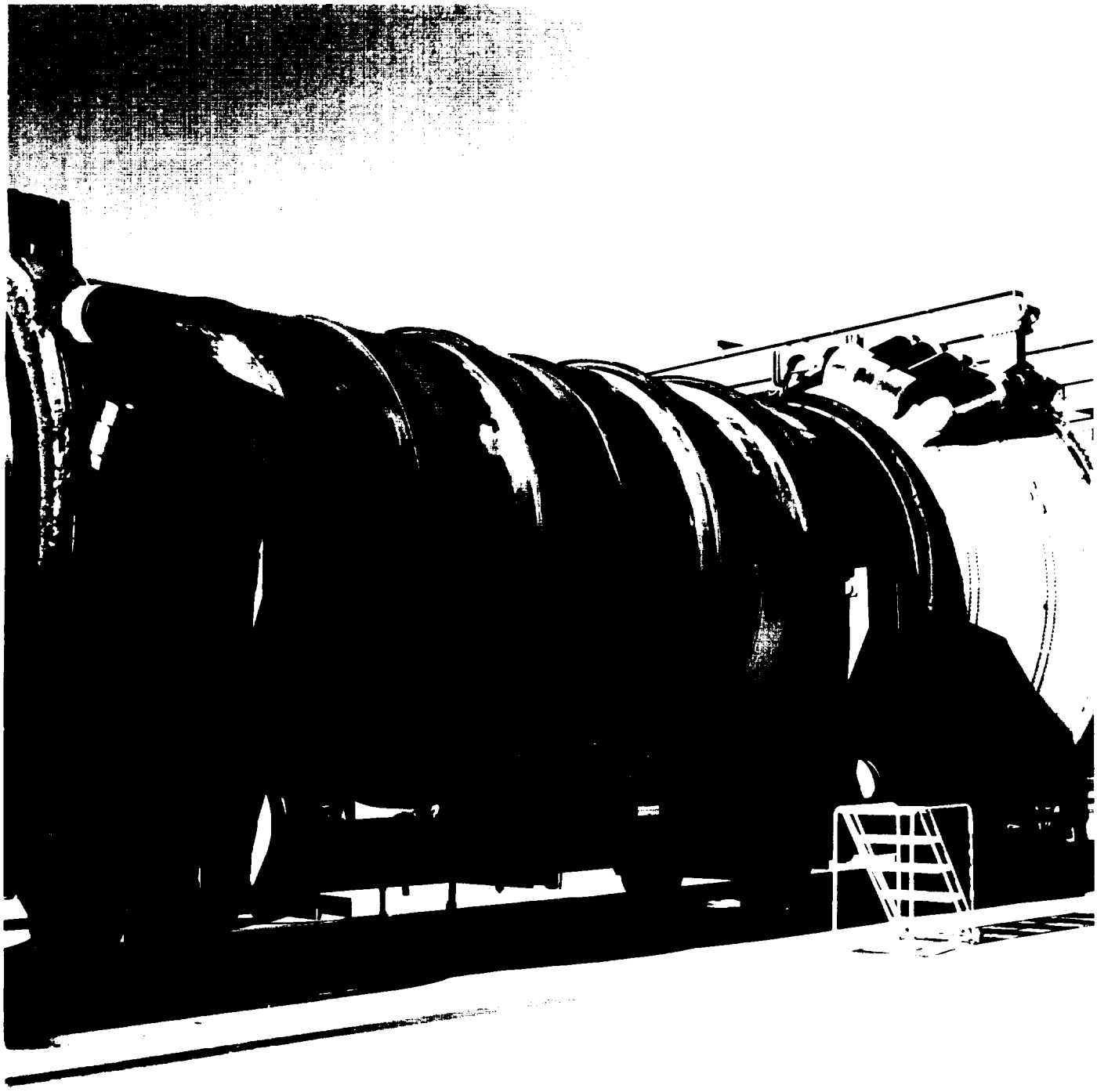


Photo 13: RH Aft Booster/Aft Skirt

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum exhibited a 2-inch diameter divot with sooted substrate between the BSM cluster and the +Y axis near the XB-275 ring frame. The number of debonds (37) over fasteners was average (Figure 2). The ten MSA-2 acreage debonds was unusual. Surveillance for unfavorable trends will continue on the next vehicle. Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.

The LH forward skirt exhibited no MSA-2 debonds. A 1-inch diameter piece of MSA-2 just forward of the EB-1 fitting was missing. Both RSS antennae covers/phenolic base plates were intact though some of the +Z antenna coating had been abraded and the phenolic base plate delaminated. None of the pins and retainer clips were missing from the frustum severance ring. However, several of the clips had been bent by parachute riser entanglement after splashdown.

The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. No K5NA was missing from the separation plane of the upper strut fairing. The ETA ring, IEA, and IEA covers appeared undamaged. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

SRB Post Launch Anomalies are listed in Section 9.

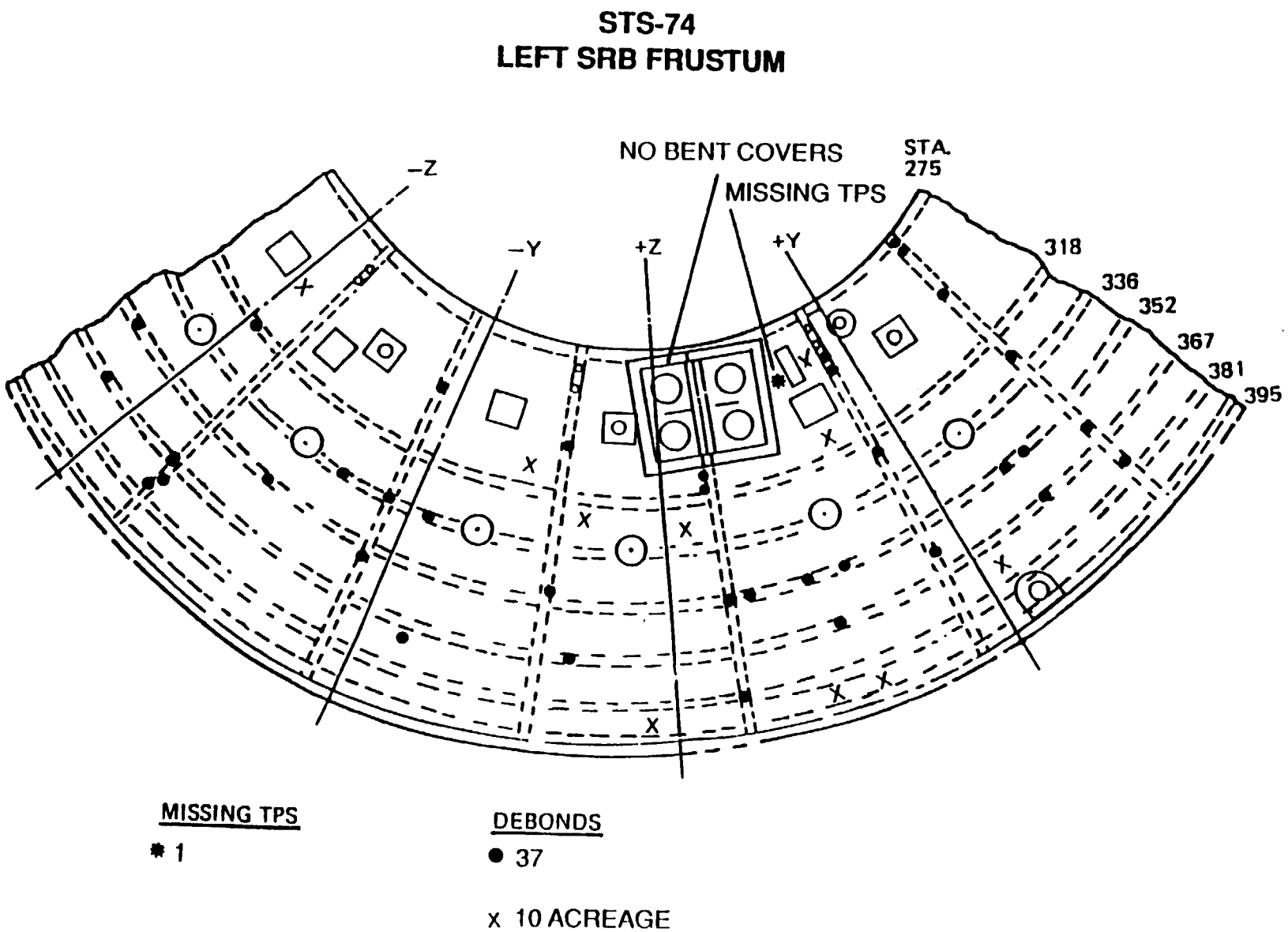


Figure 2 : LH Frustum

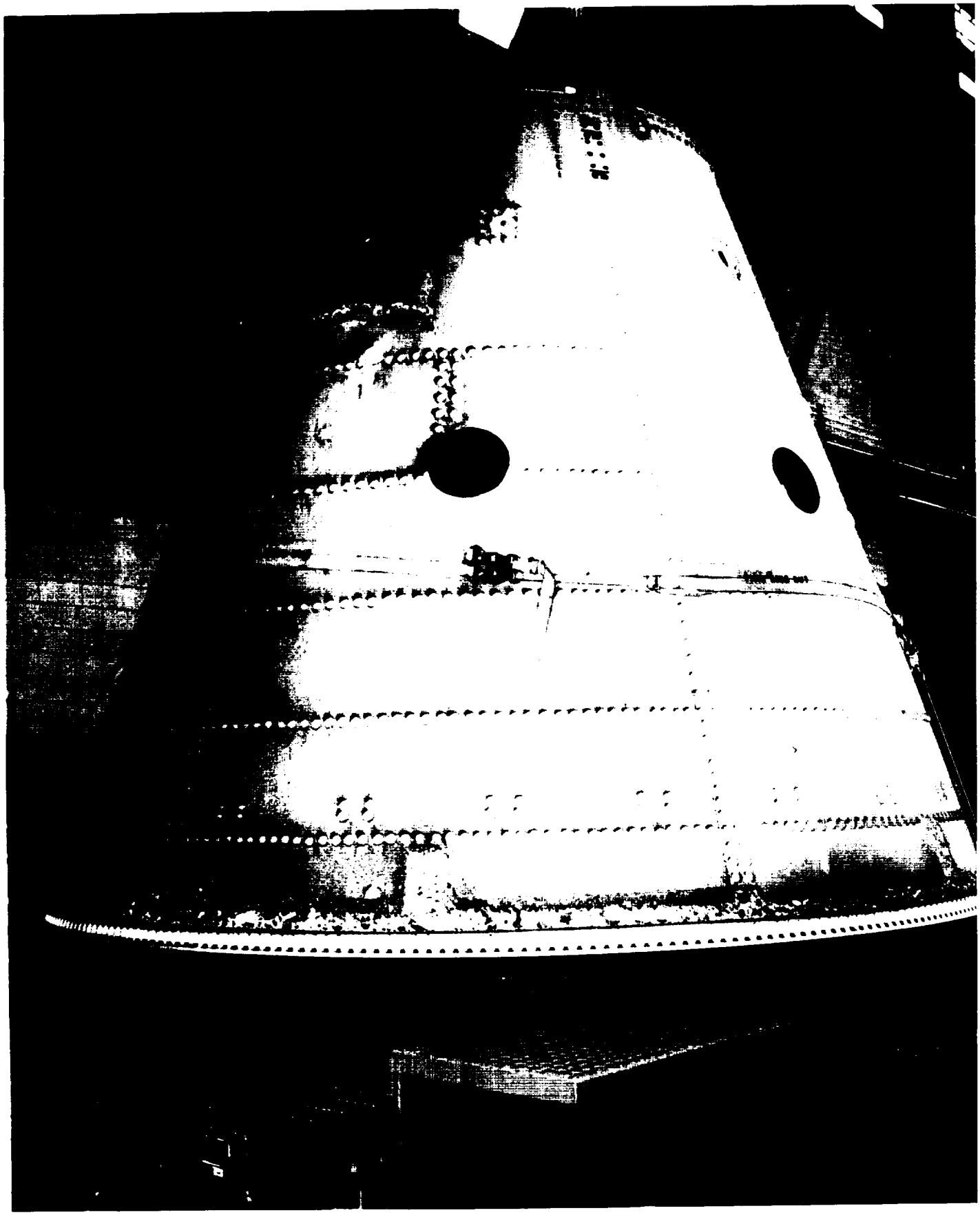


Photo 14: LH Frustum

Photo 15: LH Frustum Missing TPS

The LH frustum was missing one 2-inch diameter piece of TPS (divot) near the XB-395 ring frame between the +Y axis and the BSM cluster. The exposed substrate appeared darkened.

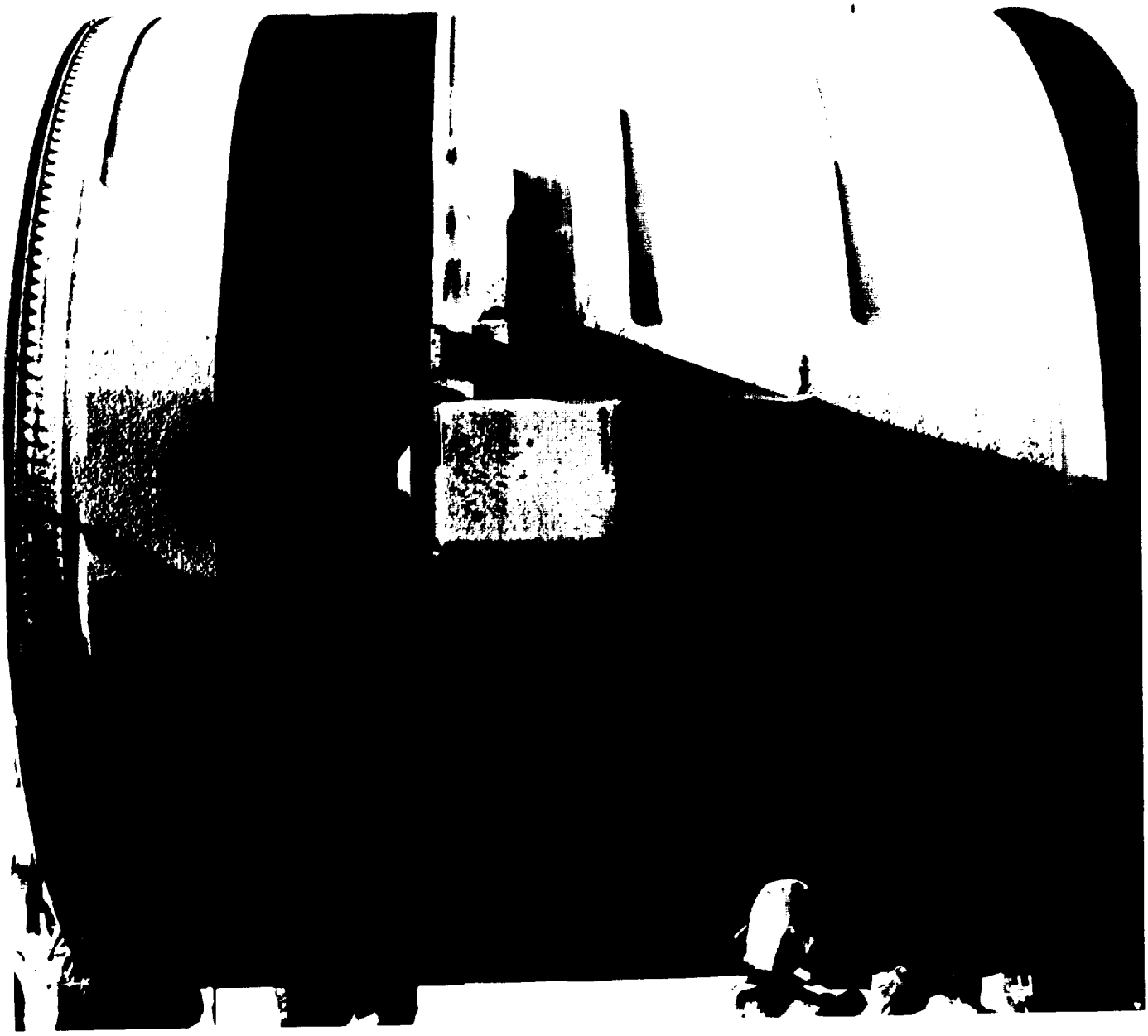


Photo 16: LH Forward Skirt

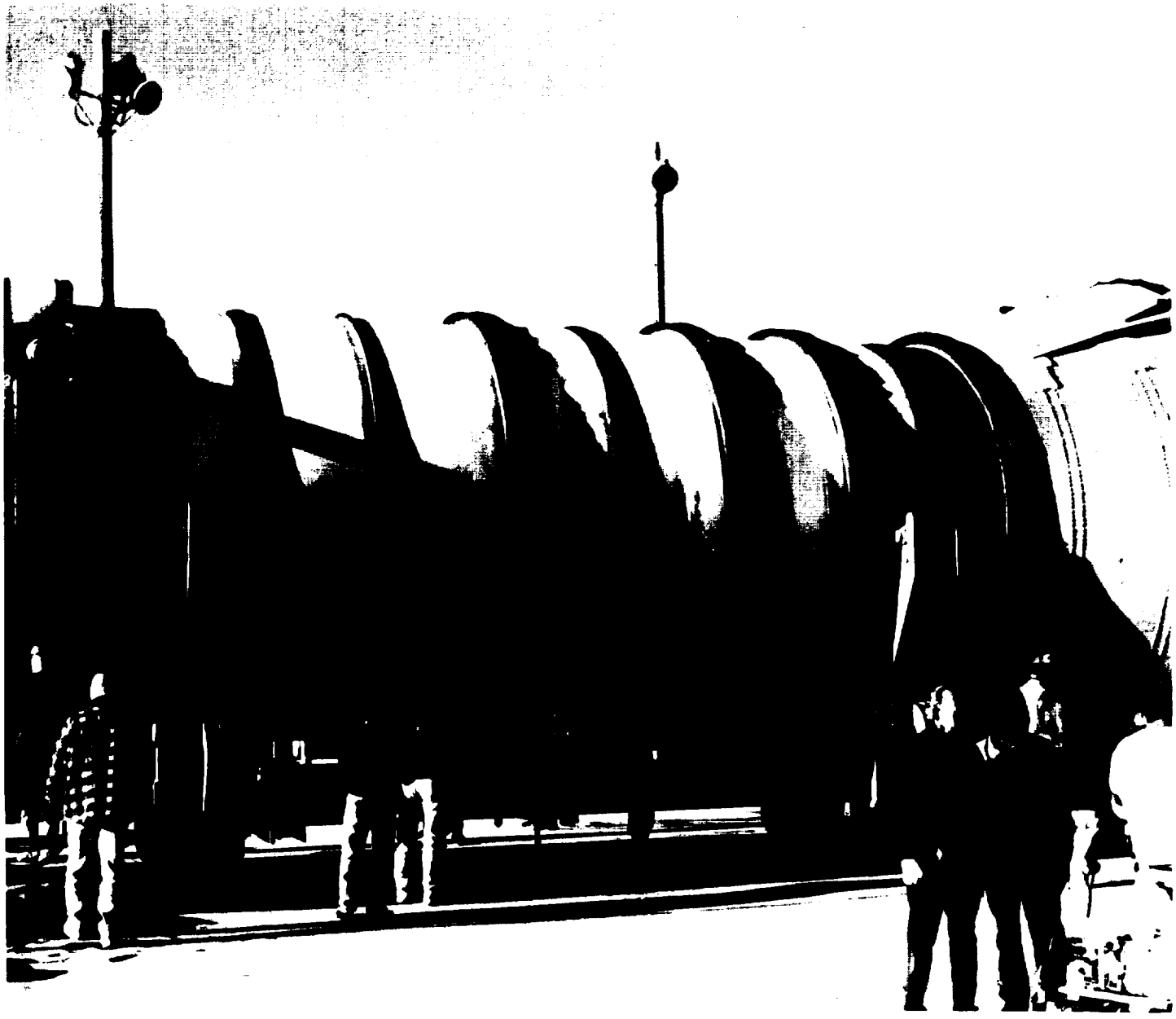


Photo 17: LH Aft Booster/ Aft Skirt

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-104 Atlantis was conducted 20-21 November 1995 at the Kennedy Space Center on SLF runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 116 hits, of which 21 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 57 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates the number of hits 1-inch or larger was average while the total number of hits was less than average (Reference Figures 3 and 4. Note: no debris impacts were recorded on the left and right sides of the fuselage. The figures have been omitted accordingly).

The following table breaks down the STS-74 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	17	78
Upper surface	1	31
Right side	0	0
Left side	0	0
Right OMS Pod	1	2
Left OMS Pod	2	5
TOTALS	21	116

Although the total number of lower surface tile damage sites was less than average, the number of damage sites 1-inch or larger was slightly above average. The largest lower surface tile damage site occurred near the Orbiter centerline just forward of the ET/ORB umbilicals. The damage site measured 3.5-inches long by 1.5-inches wide by 0.25-inch deep.

Many tile damage sites were located to the right of centerline on the lower surface. Hits in this area along a line from nose to tail are generally attributed to ice impacts from the ET LO2 feedline bellows and support brackets.

Tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals were typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream.

One gap filler aft of the NLG wheel well and two gap fillers forward of the LH MLG wheel well protruded from lower surface tiles.

No tile damage from micrometeorites or on-orbit debris was identified during the inspection.

The tires and brakes were reported to be in good condition for a landing on the KSC concrete runway.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect. One piece of debris was found on the runway after wheel stop beneath the LH2 ET/ORB umbilical cavity. The debris is believed to be purge curtain tape.

All three Dome Mounted Heat Shield (DMHS) closeout blankets were in excellent condition with no missing material. The DMHS blanket at the SSME #1 6:00 o'clock position was slightly torn and frayed. No body flap hinge stub (piano key) tiles were missing or damaged. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

No ice adhered to the payload bay door. A white residue was observed around the waste water dump nozzles. A total of seven tile damage sites, including three sites larger than 1-inch in size, were observed on the leading edge tiles of the OMS pods. A flexible insulation blanket (FIB) repair patch and the leading edge corner of another FIB were peeled back at two locations on the upper side of the left OMS pod.

Orbiter windows #3 and #4 exhibited moderate hazing and streaking. A light haze was present on the other windows. Damage to the window perimeter tiles was less than usual and concentrated in the area between windows #3 and #4. The tile damage sites were caused by impacts from FRCS paper cover pieces and RTV.

The post landing walkdown of Runway 33 was performed immediately after landing. No flight hardware was found on the runway. All drag chute hardware was recovered and appeared to have functioned normally. No unexpected hardware damage was observed on any of the drag chute components.

In summary, the number of hits 1-inch or larger was average while the total number of hits was less than average when compared to previous missions (Figure 5).

Orbiter Post Launch Debris Anomalies are listed in Section 9.

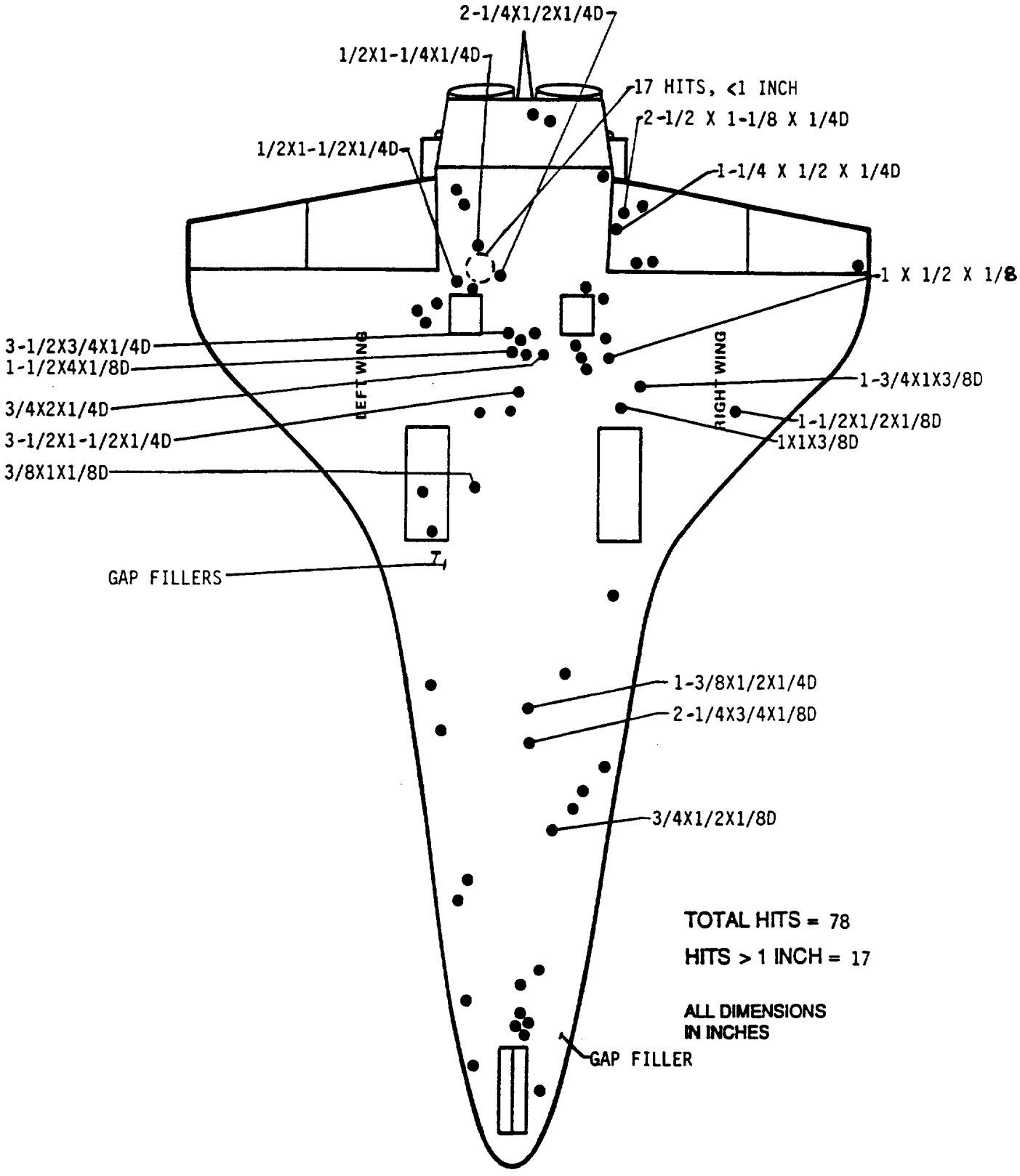


Figure 3 : Orbiter Lower Surface Debris Map

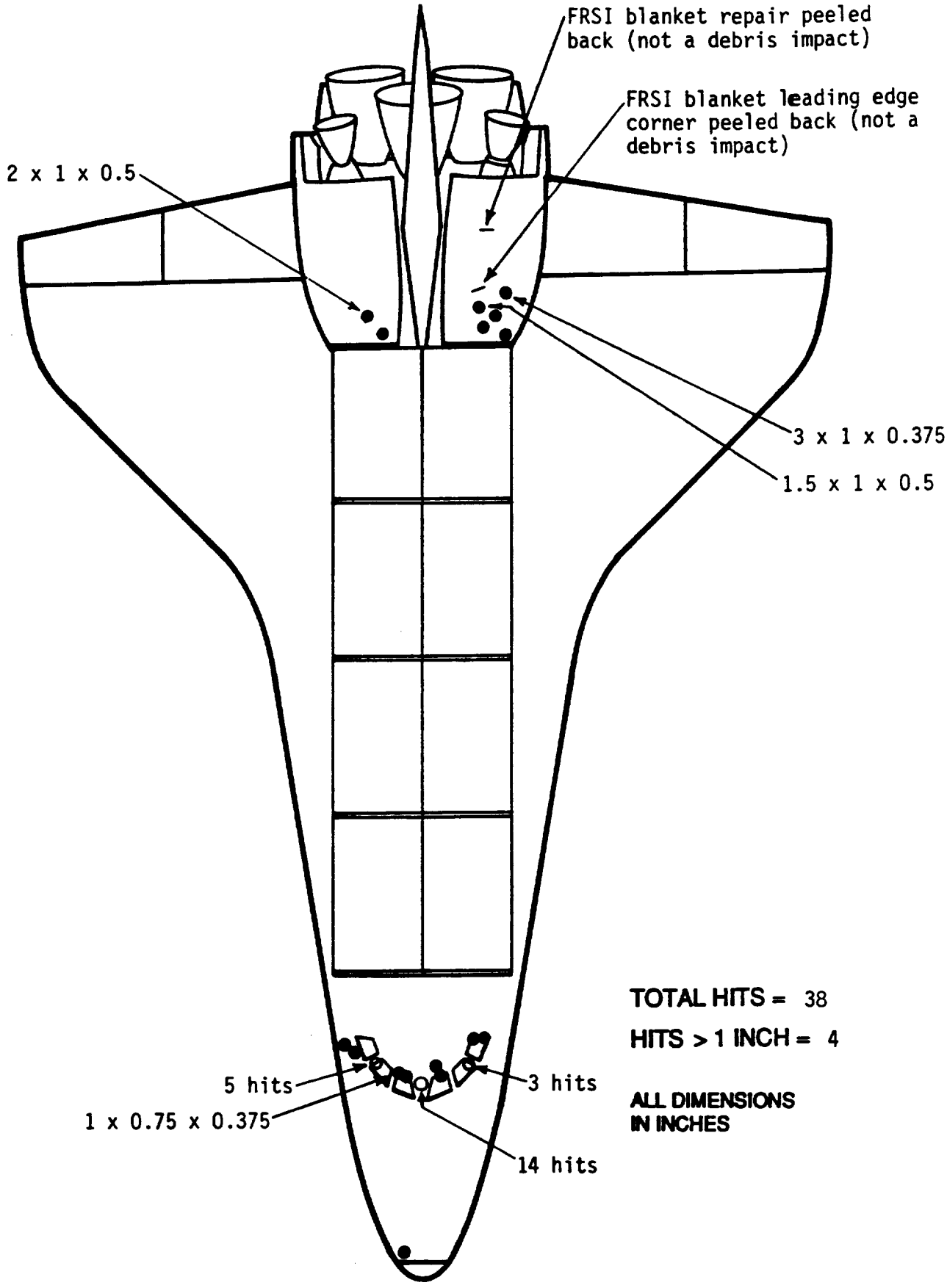


Figure 4 : Orbiter Upper Surface Debris Map

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
AVERAGE	14.1	92.2	21.1	132.4
SIGMA	7.2	43.5	9.8	54.0
STS-74	17	78	21	116

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCE

Figure 5 : Orbiter Post Flight Debris Damage Summary

Photo 18: Overall View of Orbiter Right Side

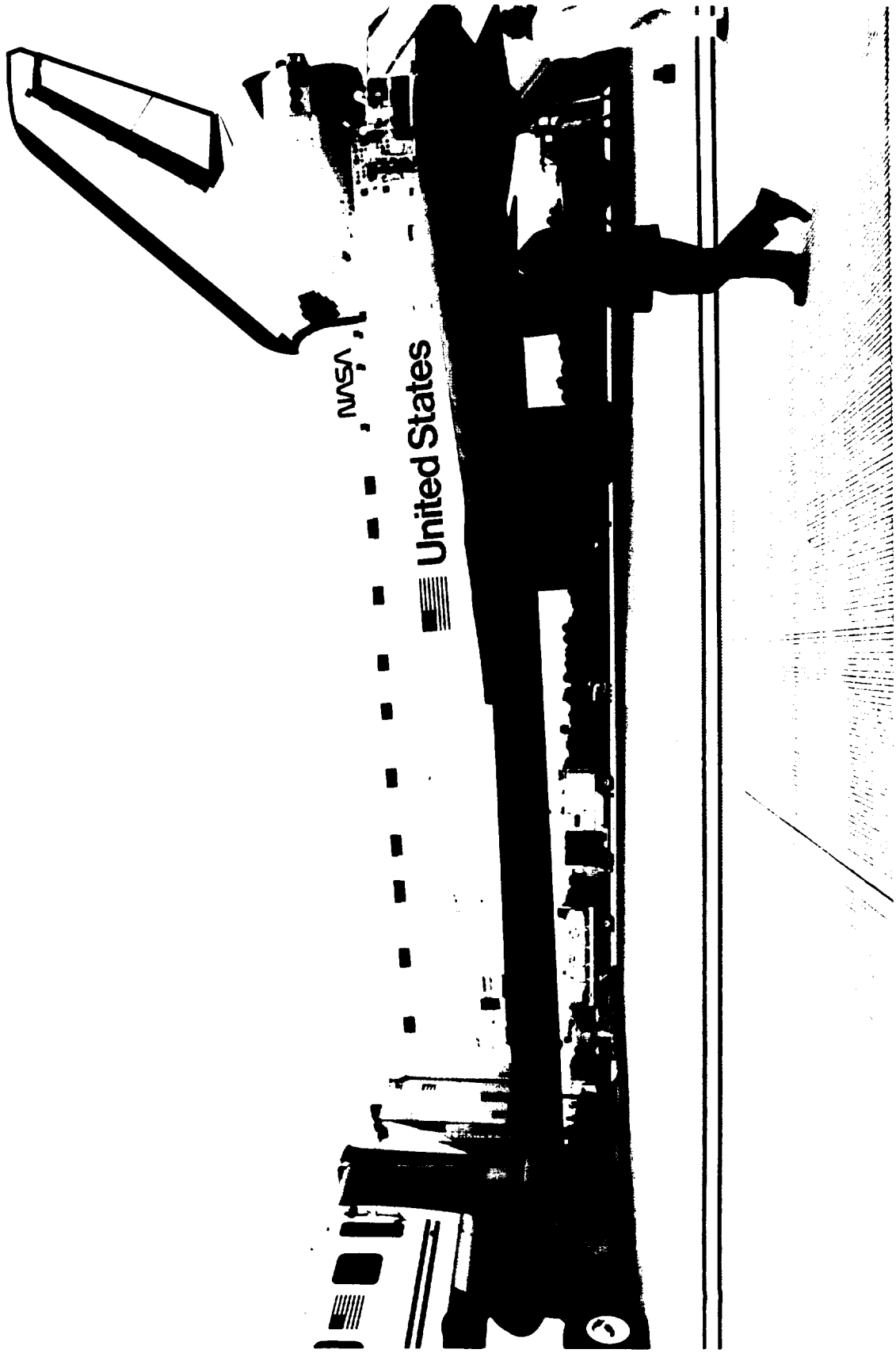


Photo 19: Overall View of Orbiter Left Side

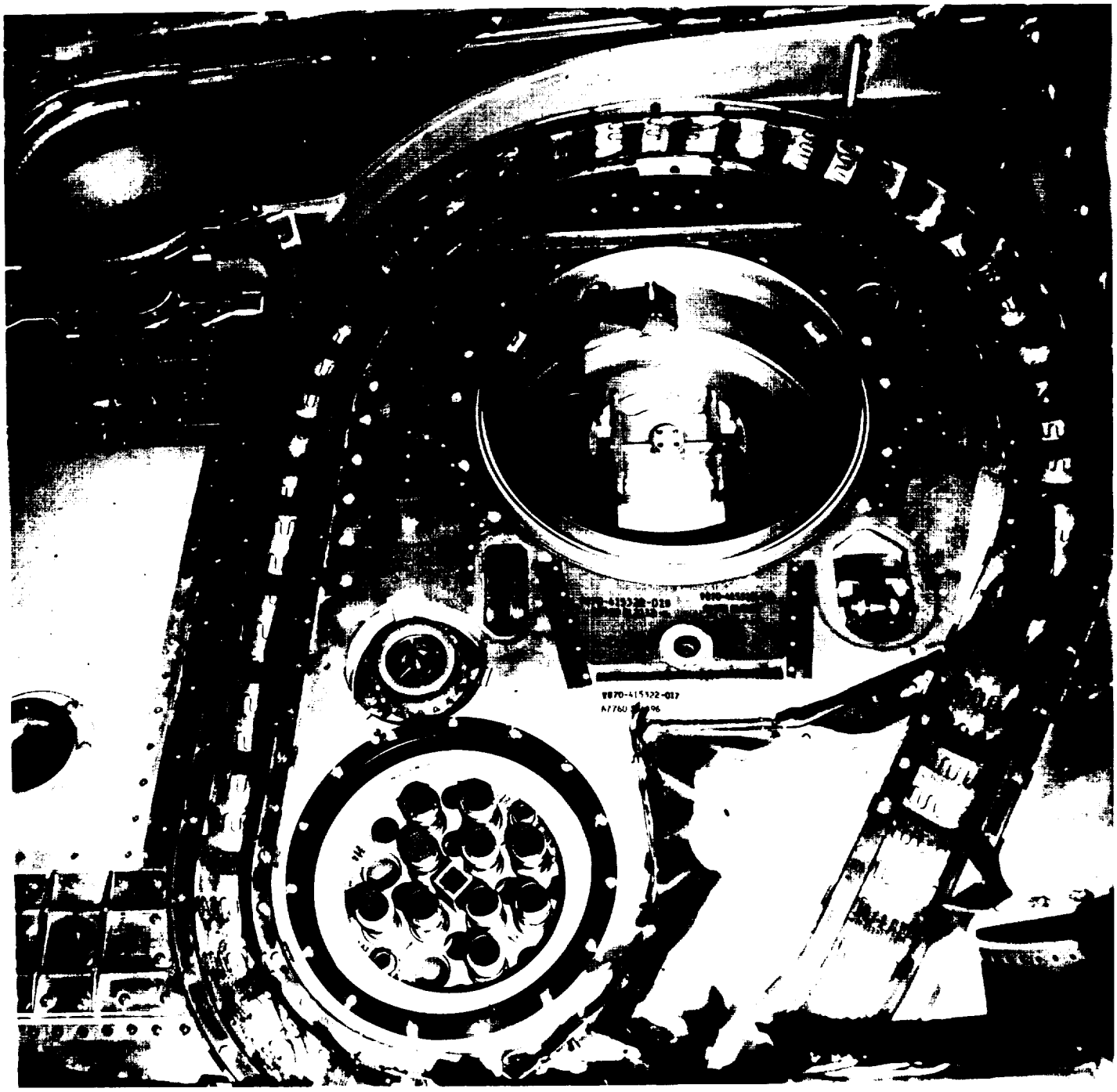


Photo 20: LO2 ET/ORB Umbilical

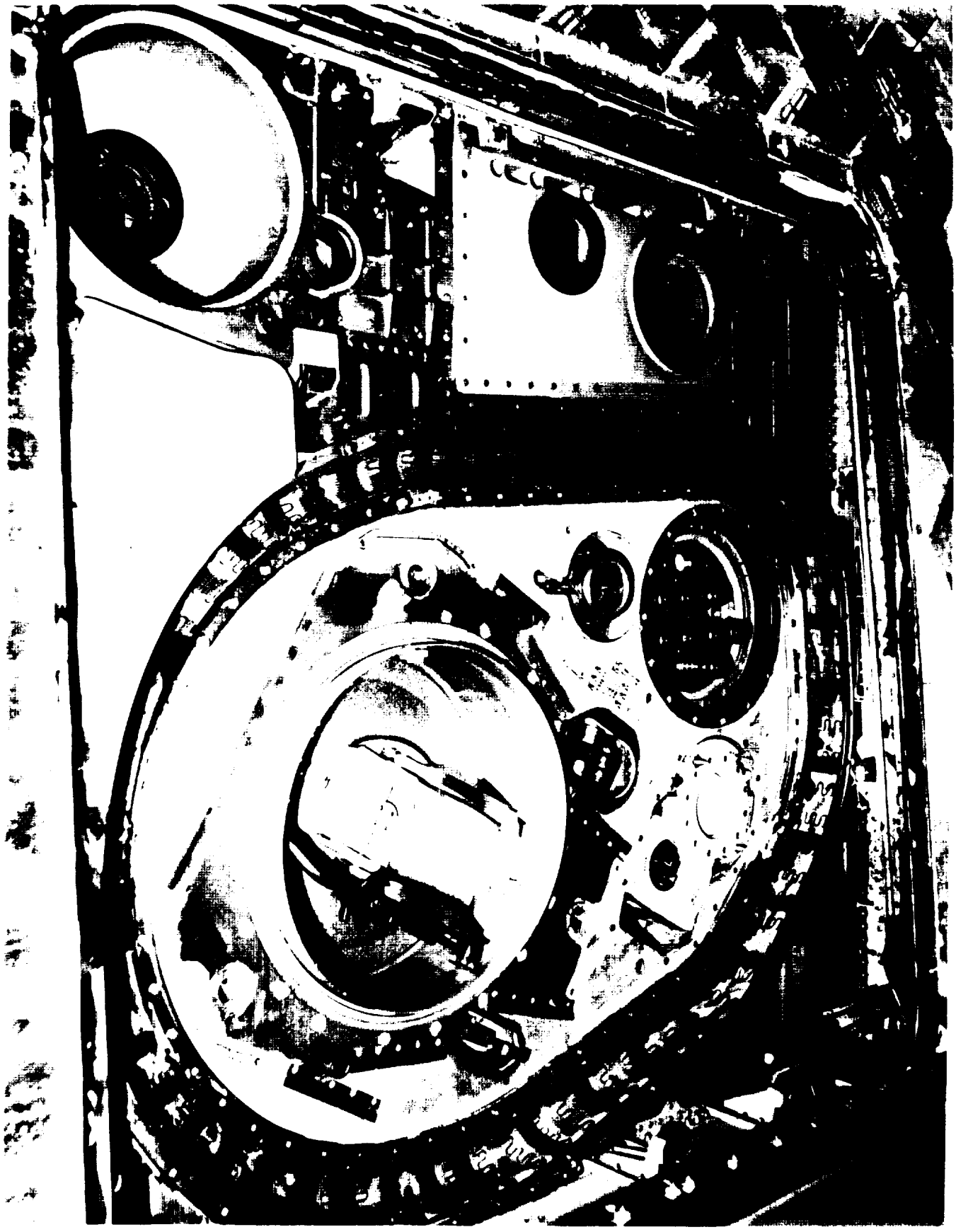


Photo 21: LH2 ET/ORB Umbilical

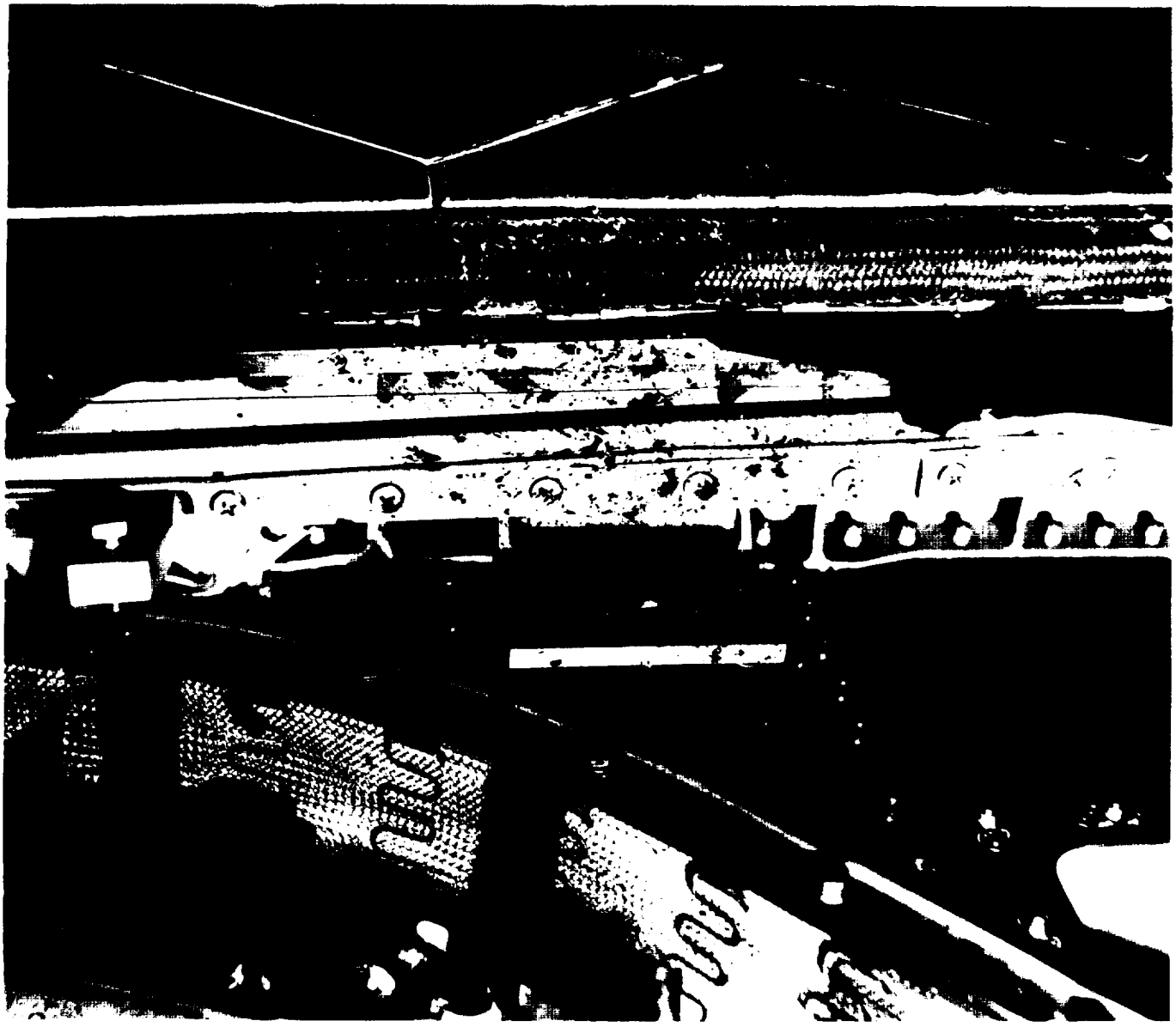


Photo 22: Debris and Exhaust Residue

Exhaust residue, small TPS particles, and debris had accumulated on the LH2 ET/ORB umbilical plate during ascent

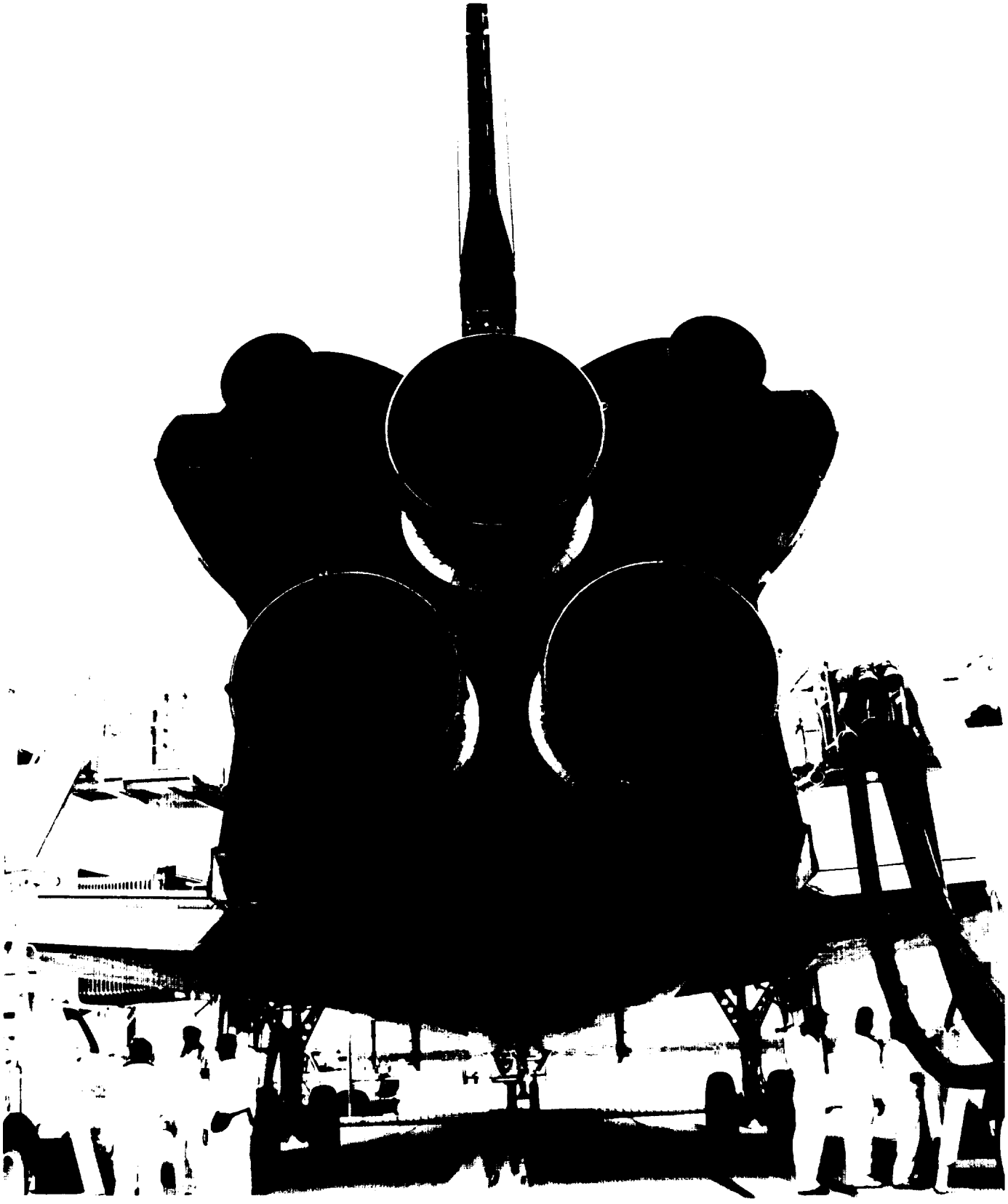


Photo 23: Base Heat Shield

Base heat shield tiles and SSME Dome Mounted Heat Shield closeout blankets were in good condition

Photo 24: Orbiter Windows

Orbiter windows #3 and #4 exhibited moderate hazing and streaking. A light haze was present on the other windows. Damage to the window perimeter tiles was less than usual and concentrated in the area between windows #3 and #4. The tile damage sites were caused by impacts from FRCS paper cover pieces and RTV.

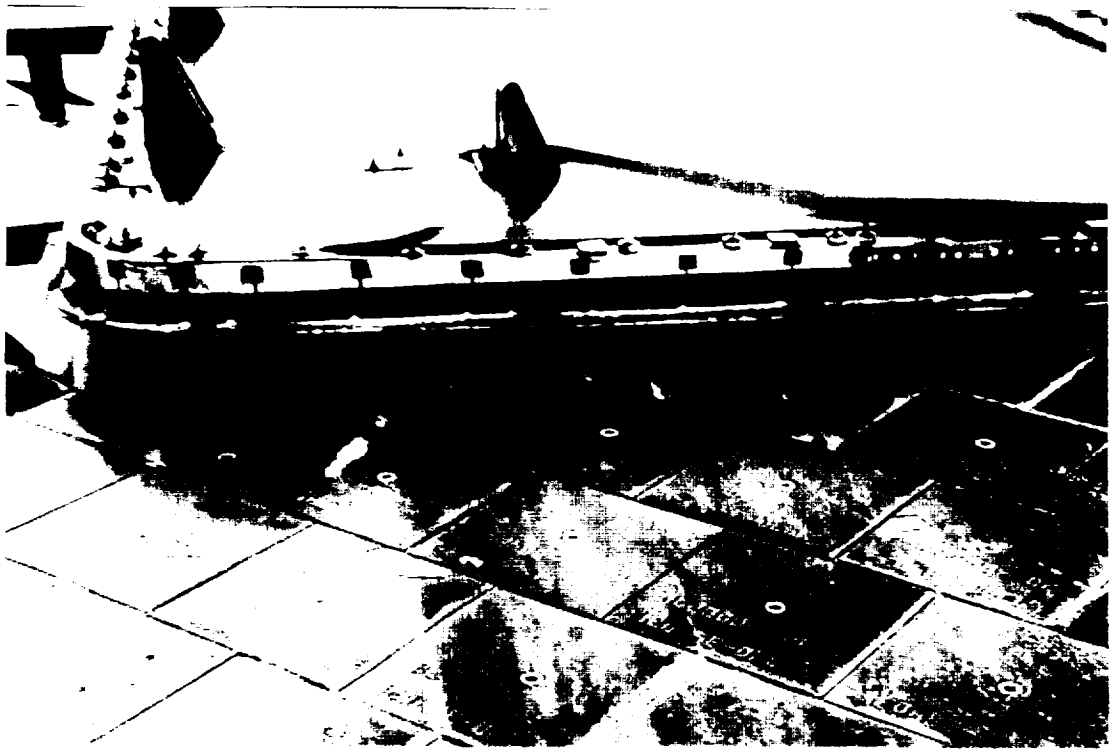


Photo 25: Lower Surface Tile Damage

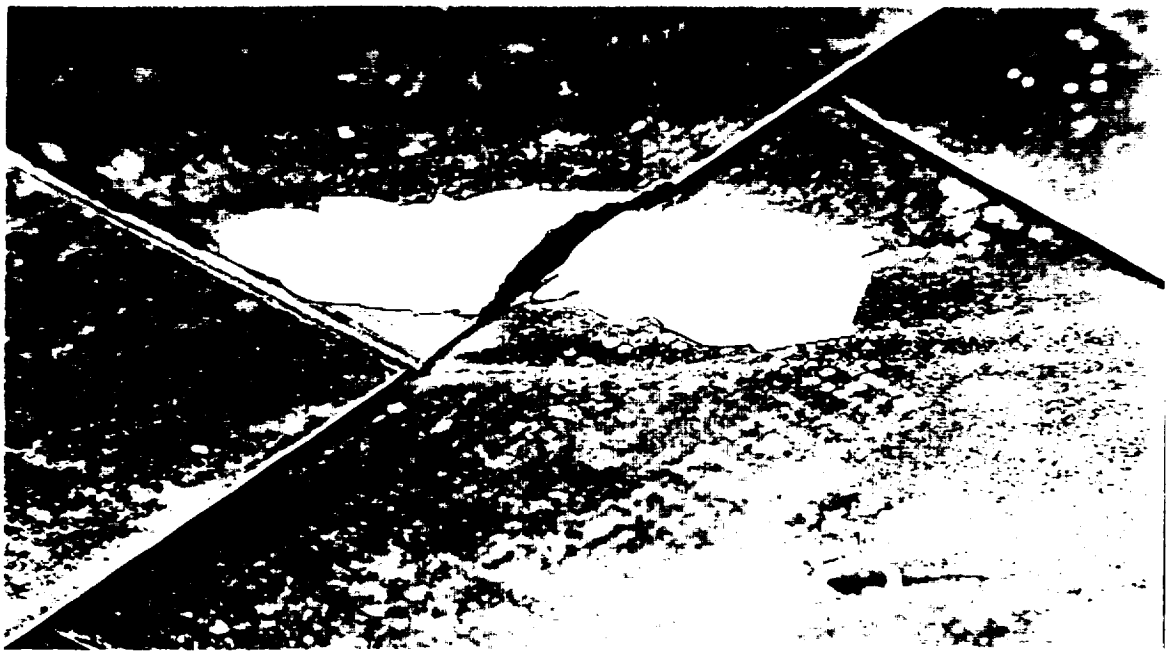


Photo 26: Lower Surface Tile Damage (Largest Damage Site)

Although the total number of lower surface tile damage sites (78) was less than average, the number of damage sites 1-inch or larger (17) was slightly above average. The largest lower surface tile damage site occurred near the Orbiter centerline just forward of the ET/ORB umbilicals. The damage site measured 3.5-inches long by 1.5-inches wide by 0.25-inch deep.

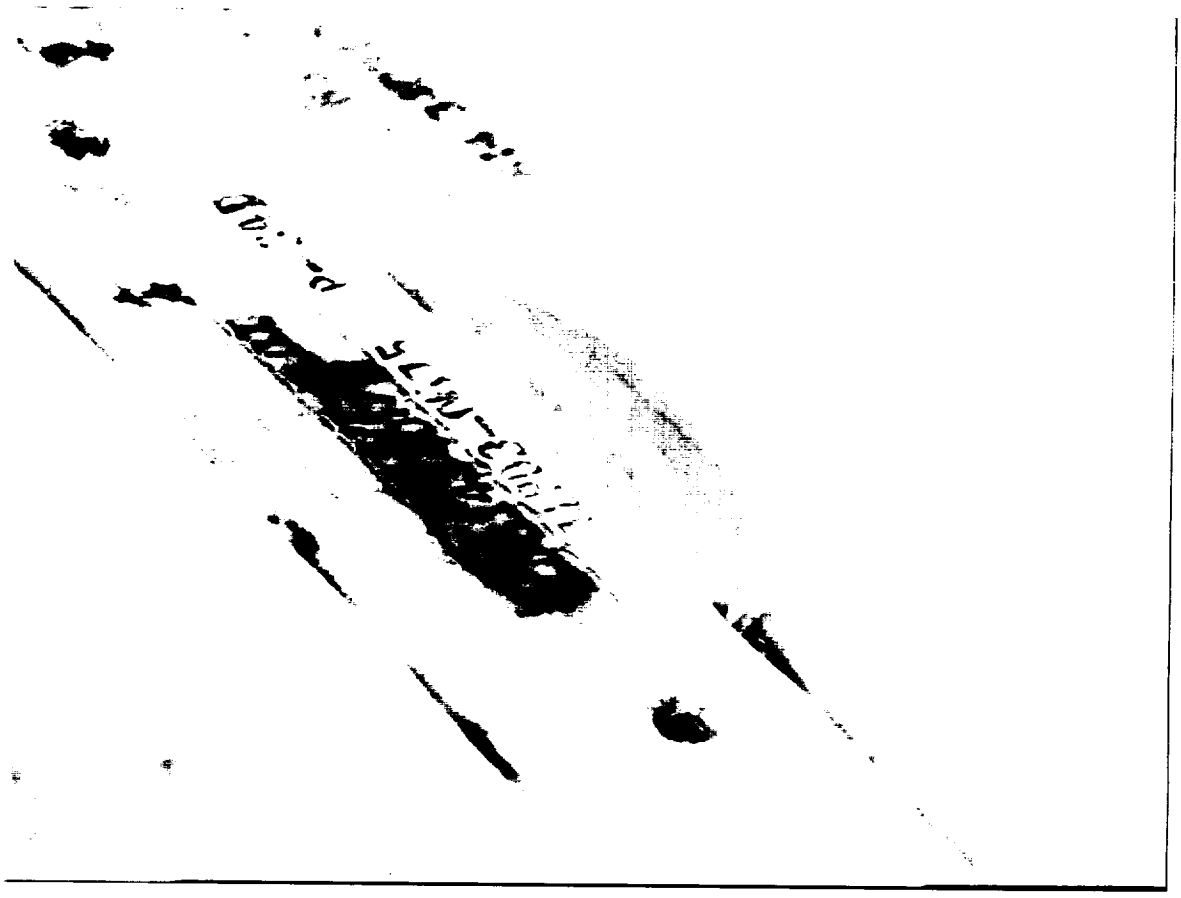


Photo 27: LH OMS Pod FIB Damage

A flexible insulation blanket (FIB) repair patch was peeled back on the upper side of the left OMS pod.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-104 Atlantis during the STS-74 post landing debris assessment at Kennedy Space Center. The submitted samples consisted of 8 wipes from Orbiter windows #1-8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

8.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to facility environment, SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (RTV and glass insulation), building type insulation, SRB sealant, Orbiter RCS nozzle cover adhesive, paints and primer from various sources. There was no apparent vehicle damage related to these residuals.

8.2 ORGANIC ANALYSIS

The results of the STS-74 organic analysis indicated the presence of plastic polymers (Orbiter window covers), RTV (Orbiter Thermal Protection System and Orbiter RCS nozzle cover adhesive), and SRB sealant. These types of organic particulate are consistent with those of the last several STS flights.

8.3 NEW FINDINGS

This set of post-flight debris residual samples led to no new findings, although the variety of residual material continues to be representative of that documented in previous mission sampling (Reference Figure 6).

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
74	Metallics - Fac.Env./BSM Residue(SRB) RTV (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics - Plastic polymers, sealant, RTV(RCS thruster nozzle cover adhesive) SRB sealant Paint and primer				
73	Metallics - Fac. Env./BSM Residue (SRB) Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Earth Minerals Organics - Plastic polymers, sealant, RTV(RCS thruster nozzle cover adhesive) Paint and primer				
69	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation glass (ORB TPS) Earth minerals Building type insulation Organics -RTV(RCS adhesive),Plastic polym Orbiter window polish residue Paint and primer				
70	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation glass (ORB TPS) Earth minerals Building type insulation Organics - RTV, Plastic polymers RTV - RCS thruster nozzle cover adhesive Paint and primer				
71	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Earth minerals (landing site) Organics - Plastic polymers RTV - RCS thruster nozzle cover adhesive Paint and primer				
67	Metallics - Fac. Env./BSM Residue (SRB) Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - sample cloth Earth minerals (landing site) Organics -RTV(RCS adhesive),Plastic polym Paint and primer				SRB sealant sample: laboratory reference

Figure 6 : Orbiter Post Landing Microchemical Sample Results

For data on previous missions refer to mission reports prior to STS-59

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
63	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile(ORB TPS) Hypalon paint (SRB)		
66	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
68	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		ET GOX Vent Seal land area and GOX Seal Sample - Metallic Particulate WINDOW DEBRIS SAMPLE - 'Butcher paper'
64	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer				
65	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
59	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer				

Figure 6 (continued) : Orbiter Post Landing Microchemical Sample Results

For data on previous missions refer to mission reports prior to STS-59

9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 5 post launch anomalies, but no In-Flight Anomalies (IFA's), were observed on the STS-74 mission.

9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. No items

9.2 SOLID ROCKET BOOSTERS

1. The LH frustum exhibited a 2-inch diameter divot with sooted substrate between the BSM cluster and the +Y axis near the XB-275 ring frame.

2. Ten MSA-2 acreage debonds were observed on the LH Frustrum. The number of acreage debonds was unusual.

9.3 EXTERNAL TANK

1. A 3-inch diameter shallow divot was observed at the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant adjacent to the PAL ramp.

2. A shallow, 2-inch diameter divot was observed on the +Y aft fairing closeout.

9.4 ORBITER

1. A flexible insulation blanket (FIB) repair patch and the leading edge corner of another FIB were peeled back at two locations on the upper side of the left OMS pod.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

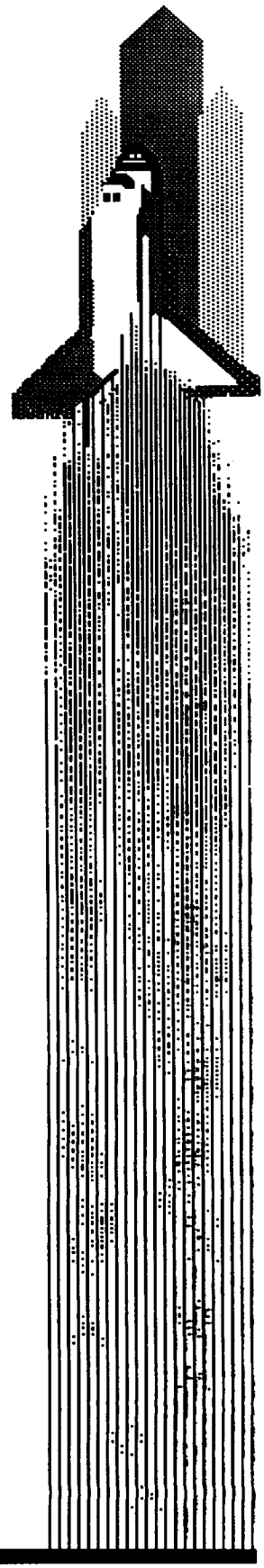
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-74 Summary of Significant Events

December 20, 1995



Space Shuttle Image Science and Analysis Group

STS-74 Summary of Significant Events

Project Work Order - SN-5CR

Approved By

Lockheed Martin

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J. M. Disler, Project Analyst
Image Science and Analysis Group

M. H. Trenchard 12/20/95
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Prepared By

Lockheed Martin Engineering and Sciences Company
for
Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

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Table of Contents

1. STS-74 (OV-104): FILM / VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-74 launch of Atlantis (OV-104) from Pad A occurred on Sunday, November 12, 1995 (day 316) at 12:30:43.024 Coordinated Universal Time (UTC) as seen on camera E9. Solid Rocket Booster (SRB) separation occurred at 12:32:46.020 UTC as seen on camera KTV13.

On launch day, 24 expected videos were received and screened. Following launch day, 52 films were screened. Camera film E204 was not received. No potential anomalies were observed during launch.

Detailed Test Objective 312, photography of the external tank after separation, was performed using the Orbiter umbilical well cameras (method 1).

1.1.2 Landing

Atlantis landed on runway 33 at KSC on November 20, 1995 at 17:01:26.820 UTC. Thirteen videos of the Orbiter's approach and landing were received.

No major anomalies were noted in any of the approach, landing, and roll-out video views screened. The drag chute deployment appeared normal.

1.2 TIMING ACTIVITIES

Launch:

Video cameras: ET208 did not have IRIG timing. All other videos had timing.

Film cameras: E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E25, E26, E30, E33, E34, E35, E36, E40, E50, E52, E54, E57, E59, E60, E62, E63, E65, E76, E77, E79, E222, and E224 had in-frame alphanumeric timing. The time codes from videos and films were used to identify specific events during the initial screening process.

Landing:
Thirteen videos were screened on landing day. Seven videos: KTV5L, KTV6L, KTV11L, KTV12L, KTV15L, KTV20L, and KTV33L had timing. There was no IRIG timing for videos SLF North, SLF South, KTV20L, EL17IR, EL18IR, SLFIR. Timing errors were present on KTV13L. The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing gear - doors opened	324:17:01:05.743	KTV6L
Right Main Wheel Touchdown	324:17:01:26.820	EL18 IR
Left Main Wheel Touchdown	324:17:01:27.088	EL18 IR
Drag Chute Initiation	324:17:01:32.358	KTV11L
Pilot Chute at Full Inflation	324:17:01:33.325	KTV11L
Bag Release	324:17:01:33.959	KTV11L
Drag Chute Inflation in Reefed Configuration	324:17:01:34.760	KTV11L
Nose Wheel Touchdown	324:17:01:36.909	EL18 IR
Drag Chute Inflation in Disreefed Configuration	324:17:01:38.497	KTV11L
Drag Chute Release	324:17:02:06.636	KTV15L
Wheel stop	324:17:02:25.021	KTV15L

Table 1.2 Landing Video Timing Events

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS

2.1.1 Debris near the Time of SSME Ignition

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition. Most of the debris were umbilical ice and RCS paper. No follow-up action was requested.

2.1.1.1 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris

(Cameras: E1, E2, E17, E18, E19, E20, E36, E76, E77, E79, OTV009, OTV049, OTV050, OTV051, OTV054, OTV070, OT0V71)

Normal ice debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at liftoff. No follow-up action was requested.

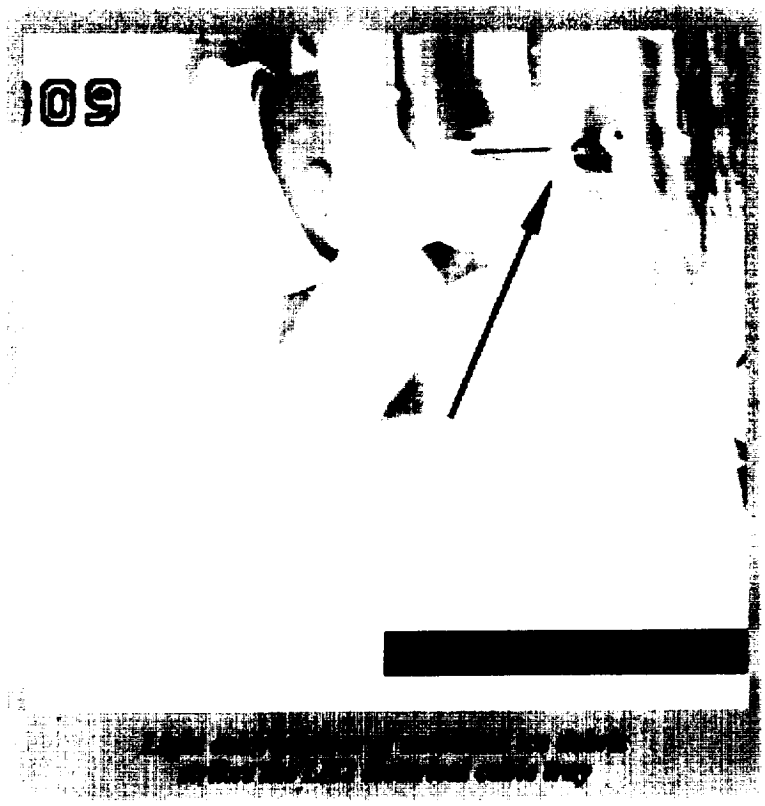


Figure 2.1.1.1 Umbilical Ice Strikes LH2 Electrical Cable Tray

Several small light colored pieces of umbilical ice were seen striking the LH2 electric cable tray during SSME ignition. No damage was noted.

2.1.1.2 Flat Rectangular Debris
(Camera: E6)

Figure 2.1.1.2 Flat Rectangular Debris Prior to Liftoff

A flat rectangular piece of debris, dark on one side and reflective on the other, was seen falling in front of the LO2 TSM in the vicinity of the right inboard elevon 0.368 seconds prior to liftoff (12:30:42.656 UTC). The debris was not seen to strike the vehicle.

2.1.2 Debris near the Time of SRB Ignition

As on previous missions, multiple pieces of debris were seen near the time of SRB ignition. No follow-up action was requested.

2.1.2.1 Several Small light Colored Pieces of Debris
(Cameras: E30, E36)

Several small light colored pieces of debris were seen to travel between the camera and the LSRB at SRB ignition. The debris did not appear to strike the vehicle.

2.1.2.2 Small Dark Piece of Debris near the RSRB Holddown Post M-2 DCS

(Camera: E8)

A small dark piece of debris was seen near the RSRB Holddown post M-2 Debris Containment System (DCS) just after PIC firing (12:30:43.070 UTC).

2.1.2.3 SRB Flame Duct Debris

(Cameras: E4, E30, E57, E77)

As on previous missions, debris was noted originating from the SRB flame duct area after SRB ignition. No follow-up action was requested.

A light colored piece of debris was seen to travel from the SRB flame duct across the MLP deck at liftoff (12:30:43.466 UTC).

Figure 2.1.2.3 Debris seen Coming from the RSRB Flame Duct

On camera E4, approximately six pieces of light colored debris were seen coming from the RSRB flame duct just after SRB ignition (12:30:44.355 UTC).

On camera E57, several pieces of light colored debris were seen coming from the SRB flame duct at SRB ignition (12:30:44.503 UTC). On camera E77, multiple pieces of light colored debris were seen aft of the left and right Orbiter wings at liftoff (12:30:44.648 UTC). The debris aft of the wings appeared to be the same debris seen coming from the SRB flame duct that was seen on camera E57. None of the flame duct debris was seen to strike the vehicle.

2.1.2.4 Debris at T+1 Second
(Camera: E26)

Several pieces of light colored debris fell aft along the LSRB at liftoff (12:30:44.187 UTC). The debris appeared to be coming from the FSS. The debris was not seen to strike the vehicle.

2.1.2.5 Debris at T+2 Seconds
(Cameras: E65, E79)

A small light colored piece of debris was seen falling aft along the Orbiter fuselage tiles forward of the ET/Orbiter umbilicals at liftoff (12:30:45.719 UTC). On camera E79, a light colored piece of debris was seen falling aft along the external tank LO2 feedline at liftoff (12:30:45.989 UTC). The debris was not seen to contact the vehicle. The origin of the debris was not seen.

2.1.2.6 LH2 and LO2 Tail Service Mast (TSM) T-0 Umbilical Disconnect Debris
(Cameras: OTV050, E17, E18, E19, E20, E31, E63, E76, E77)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at liftoff. None of the debris was observed to strike the vehicle.

2.1.2.7 GH2 Vent Arm Debris During Disconnect and Retraction
(Cameras: E33, E34, E35, E50, E54, E59, E60)

The GH2 vent arm appeared to retract normally. Vapor and multiple light colored pieces of ice debris fell from the GH2 vent arm carrier plate at vent arm retraction. Vapor and ice were seen coming from the external tank GH2 vent after liftoff (12:30:48.520 UTC). This event has been seen on previous missions and is not considered anomalous.

2.1.3 Debris After Liftoff

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) at liftoff, throughout the roll maneuver and beyond on the launch tracking views. The debris was probably reaction control system (RCS) paper and ice from the ET/Orbiter umbilicals. None of the debris was seen to contact the launch vehicle. No follow-up action was requested.

2.1.3.1 Debris at T+5 Seconds
(Camera: OTV041)

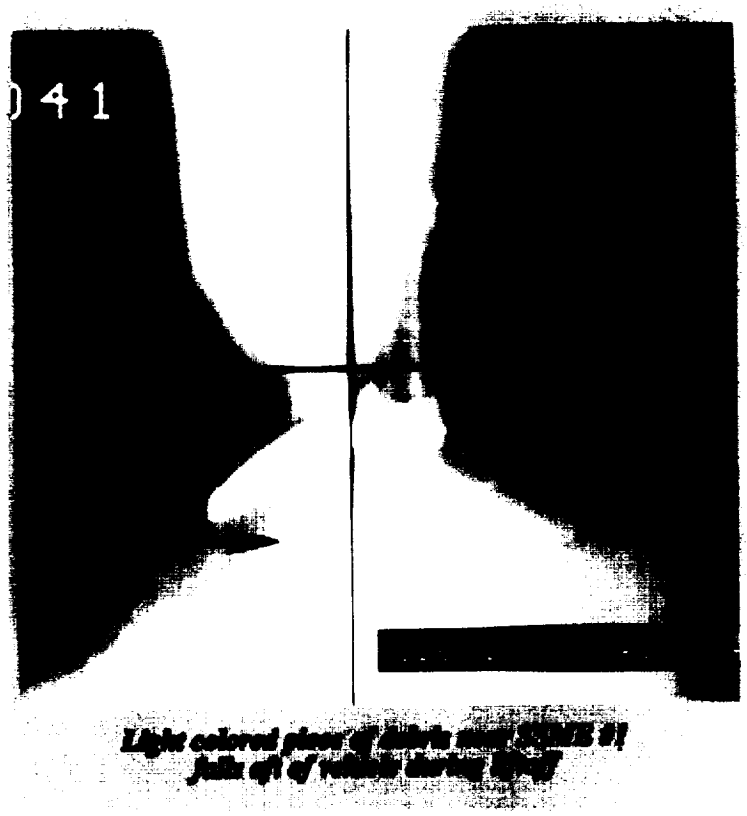


Figure 2.1.3.1 Debris near SSME #1 at Liftoff

A light colored piece of debris first noted near SSME #1 fell aft of the vehicle during liftoff (12:30:48.984 UTC).

2.1.3.2 Light Colored Debris Contacted SSME Exhaust Plume at T+10 Seconds MET
(Camera: E52)

A light colored piece of debris first seen over the left wing fell aft into the SRB exhaust plume during ascent (12:30:53.759 UTC).

2.1.3.3 Debris near RSRB Aft Skirt
(Camera: E57)

A light colored piece of debris was seen falling aft out of the RSRB exhaust plume near the RSRB aft skirt during ascent at approximately 14.3 seconds MET (12:30:57.319 UTC).

2.1.3.4 Light Colored Debris Contacts SSME Exhaust Plume at T+48 and T+67 Seconds MET

(Camera: E223)

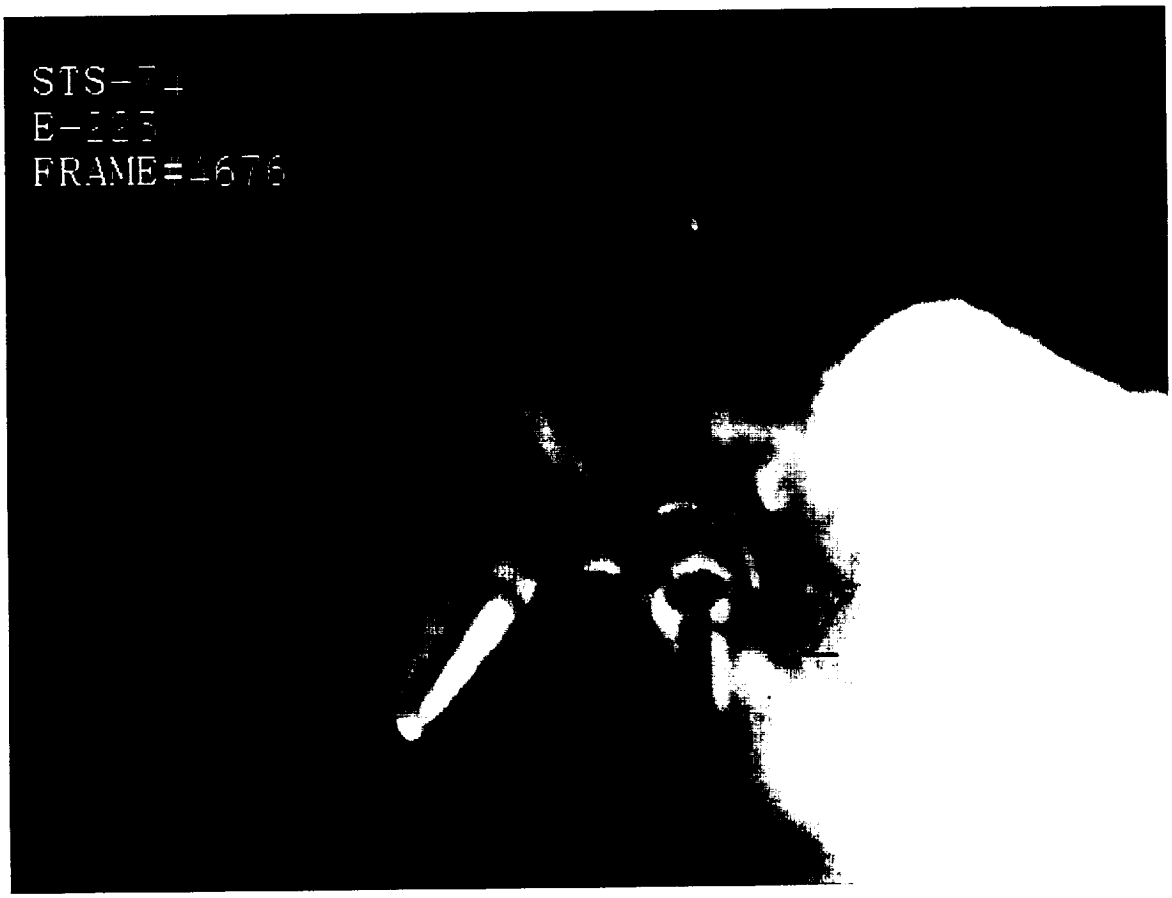


Figure 2.1.3.4 Debris in SSME Exhaust Cloud causes a Flare

A light colored piece of debris seen between the SRB aft skirts contacted the SSME exhaust plume causing an orange colored flare at approximately 48 seconds MET. A separate event observed at approximately 67 seconds MET was a light colored piece of debris that exited the SRB exhaust plume.

2.2 MOBILE LAUNCH PLATFORM (MLP) EVENTS

2.2.1 Orange Vapor

(Cameras: E3, E5, E6, E20, E36, OTV070)

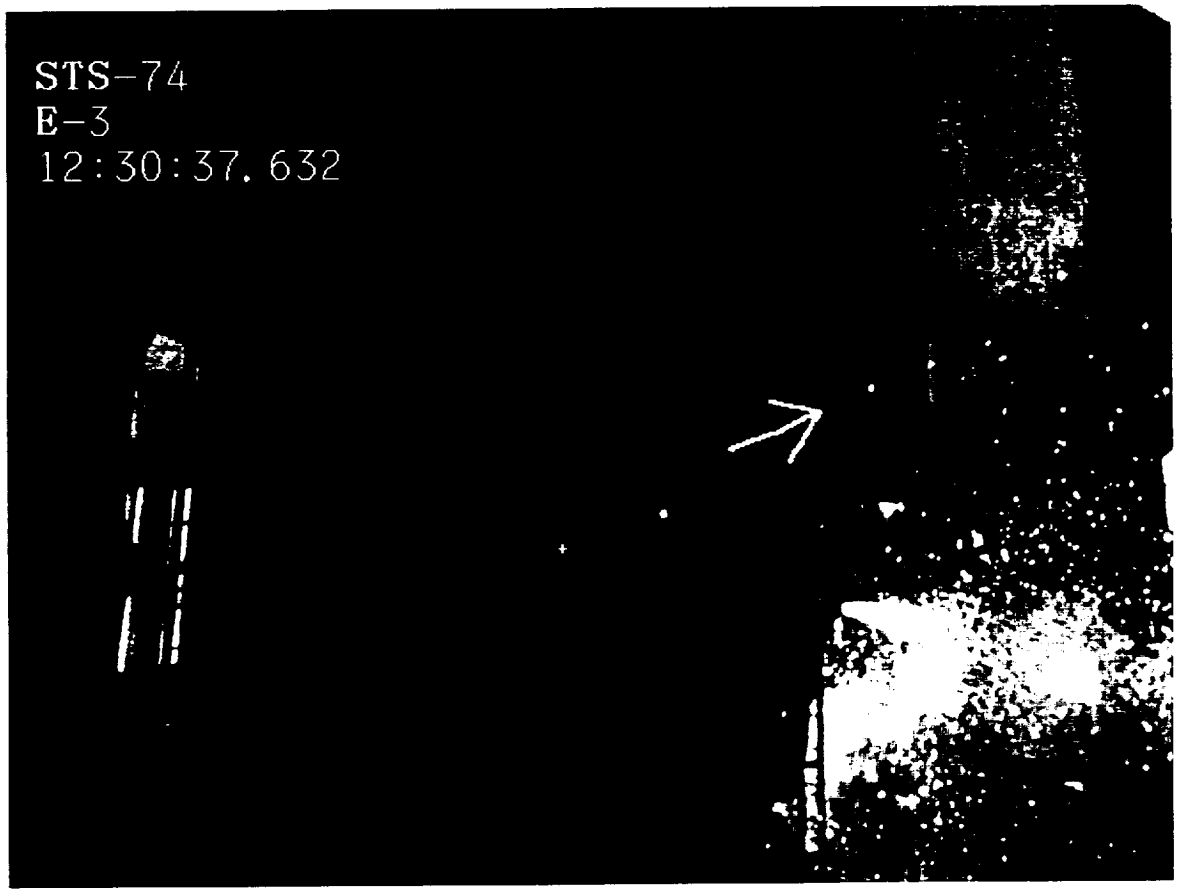


Figure 2.2.1 Orange Vapor near the Left RCS Stinger

Orange vapor (possibly free burning hydrogen) was seen forward of the main engines in the vicinity of the left RCS stinger, near the left OMS pod, and near the body flap during SSME startup (12:30:37.739 UTC). Orange vapor forward of the main engines has been seen on previous missions. No follow-up action was requested.

2.2.2 TPS Erosion on Body Flap and Base Heat Shield

(Cameras: E18, E19, E20)

Several areas of TPS erosion were seen on the upper surface of the body flap outboard of SSME #3 during SSME startup (12:30:40.7 UTC). Small areas of TPS erosion were also seen on the base of the left RCS stinger (12:30:38.720 UTC) and on the base heat shield outboard of SSME #2 (12:30:38.5 UTC). Similar TPS erosion has been seen on previous missions. No follow-up action was requested.

2.2.3 RCS Paper Discoloration

(Cameras: OTV049, OTV051, OTV070)

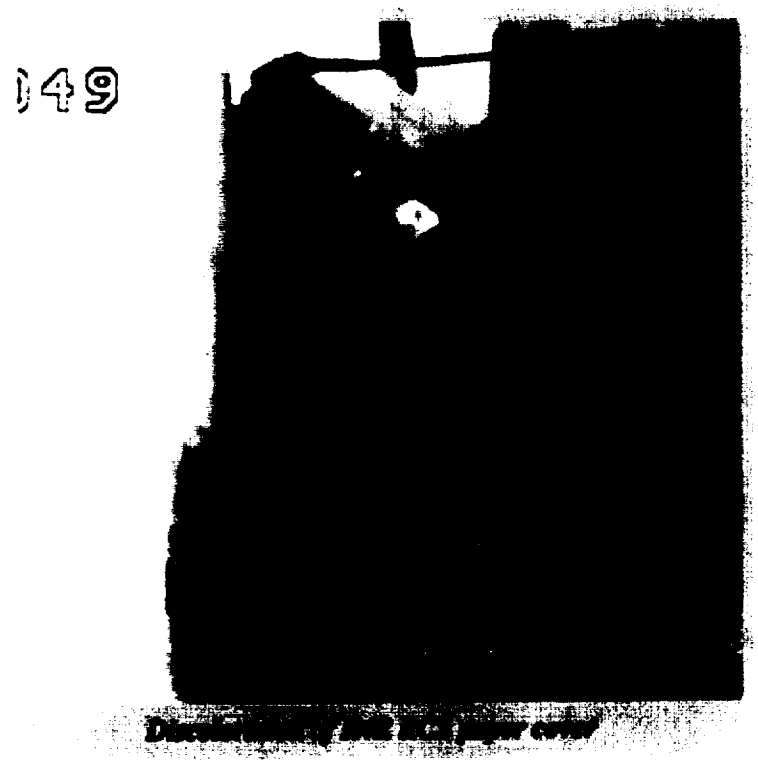


Figure 2.2.3 Discoloration of RCS Paper Cover

Discoloration of the R4R, R1U and R4U RCS paper covers was noted. Discoloration of the RCS paper covers has been seen on previous missions and is not considered anomalous. No follow-up action was requested

2.2.4 SSME Mach Diamond Formation

(Cameras: OTV051, E19, E20)

The SSME Mach diamonds formed in the normal sequence. The times of the Mach diamond sequence were:

SSME #3 - 316:12:30:39.707 UTC
SSME #2 - 316:12:30:39.802 UTC
SSME #1 - 316:12:30:39.961 UTC

2.3 ASCENT EVENTS

2.3.1 Orange Flare in SSME Exhaust Plume
(Camera: E224)

An orange colored flare (probably due to debris) was seen in the SSME exhaust at approximately 48.5 seconds MET (12:31:31.449 UTC). Flares in the SSME exhaust plumes have been seen on previous mission launch films. No follow-up action was requested.

2.4 ANALYSIS OF THE UMBILICAL WELL CAMERA FILMS (TASK #5)

Two rolls of STS-74 umbilical well camera film were acquired: the 35 mm film from the LO2 umbilical and one 16 mm film (5 mm lens) from the LH2 umbilical. The 16 mm film with the 10 mm lens from the LH2 umbilical did not run. The +X translation maneuver was performed on STS-74.

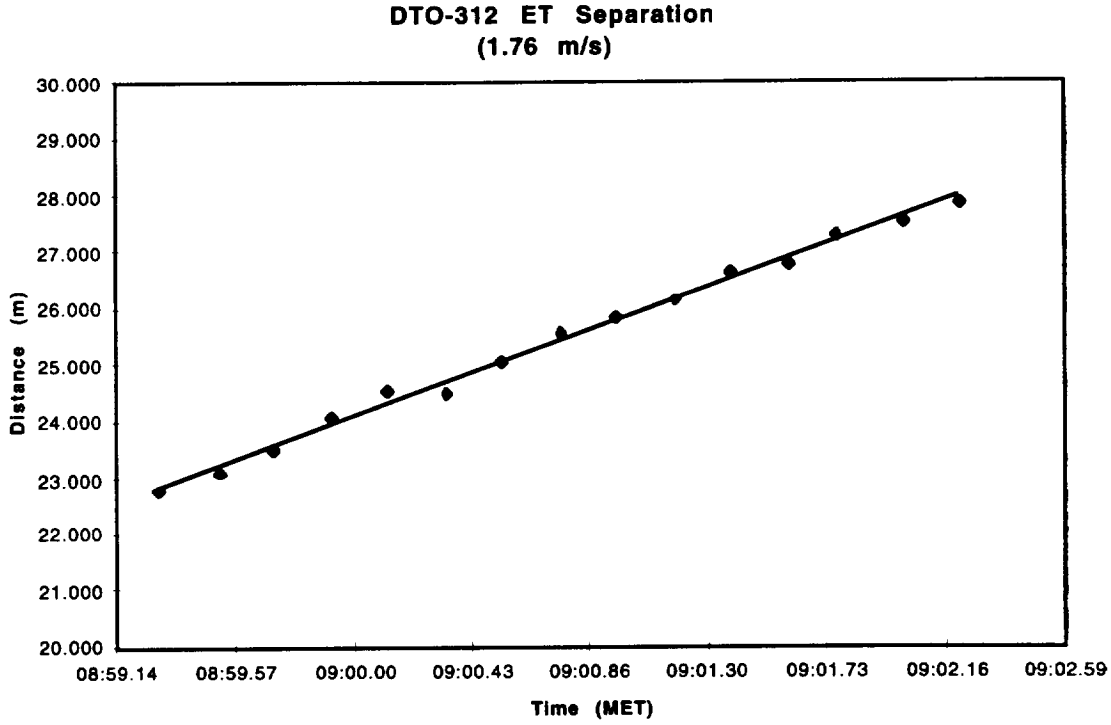


Figure 2.4 ET Separation Velocity.

Using the 16 mm LH2 umbilical well camera film (5 mm lens), the external tank distance was calculated over a 700 frame squence. The external tank was calculated to be a distance of 22.8 meters away from the Orbiter at 8:59.29 MET; 2.92 seconds later at 9:02.21 MET the tank was calculated to be at 27.9 meters. The tank separation velocity was determined to be 1.8 meters per second.

2.4.1 35 mm LO2 Umbilical Well Film Screening

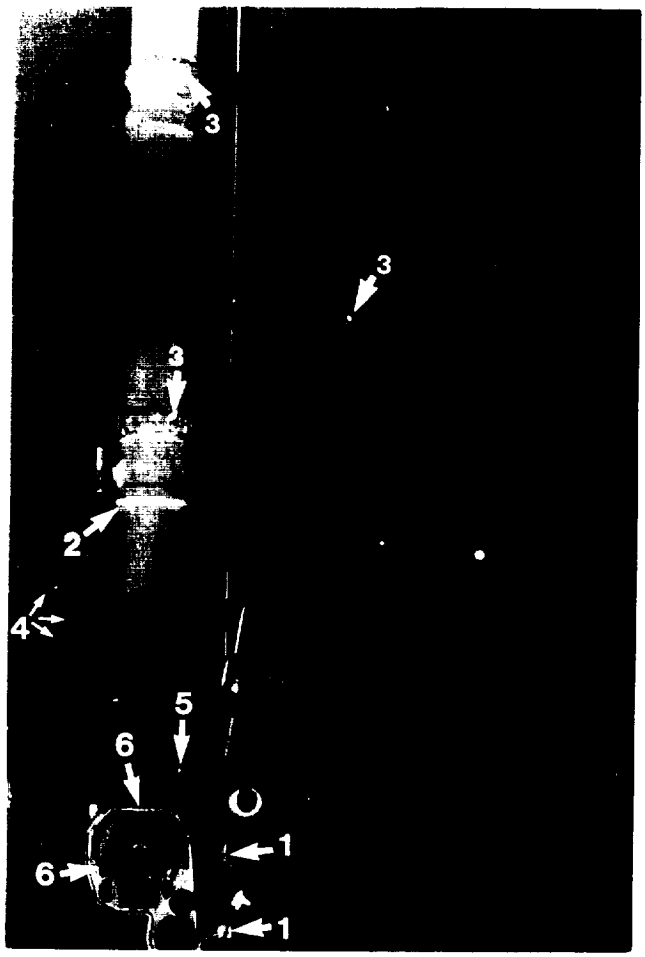


Figure 2.4.1 (A) LO2 Umbilical/Aft ET

Numerous areas of minor TPS erosion were visible on the horizontal and vertical sections of the LO2 cable tray (1). Ice/frost was visible on the LO2 aft bellows on the LO2 feedline (2). TPS erosion was visible on the LO2 feedline flange closeouts and the forward end of the +Y thrust strut (3). The typical shallow "popcorn" divots forward of the crossbeam were present (4). A shallow (appearing) divot was visible on the closeout fairing forward of the LO2 umbilical (5). All of the lightning contact strips were present and intact on the LO2 umbilical (6).

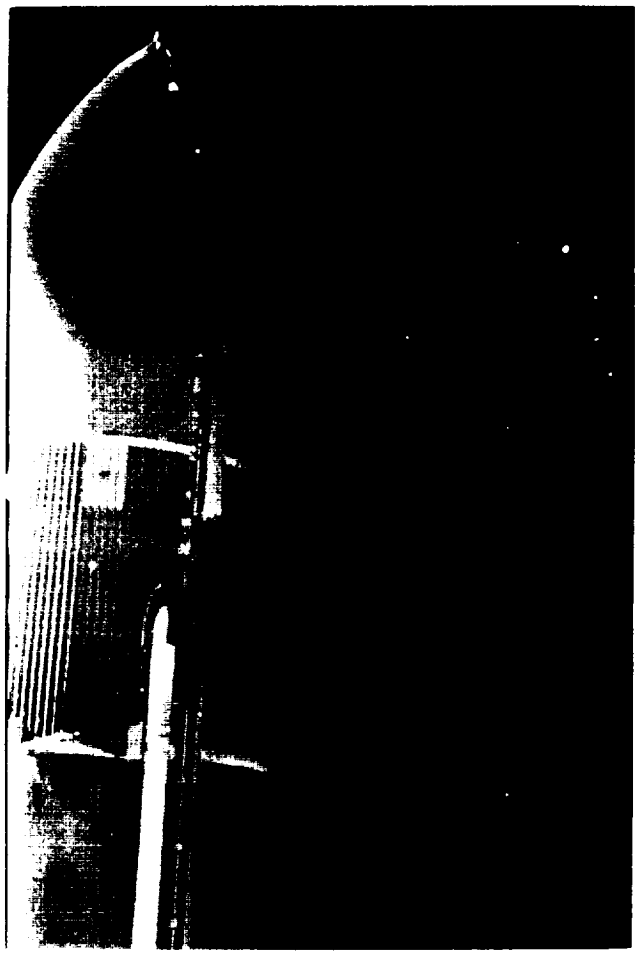


Figure 2.4.1 (B) Forward ET

A shallow (appearing) divot was visible on the LH2 tank-to-intertank flange closeout adjacent to the air load ramp (1). The LH2 tank, the intertank, and the nose section of the external tank appeared in good condition. The jack pad closeouts beneath the ET/Orbiter forward bipod attach, that have been damaged on some previous mission tanks, were in good condition on the STS-74 tank (2).

Multiple, small, white debris objects were visible through out the film sequence. These white debris objects appear to be frozen hydrogen.

2.4.2 16 mm LH2 Umbilical Well Film Screening (5 mm Lens)

Numerous light colored pieces of debris (probably insulation) were in view throughout the SRB film sequence. Typical chipping and erosion of the electric cable tray was visible. Multiple pieces of white debris (frozen hydrogen) were visible throughout the ET separation sequence. These events are typical of those seen on previous mission umbilical well camera views.

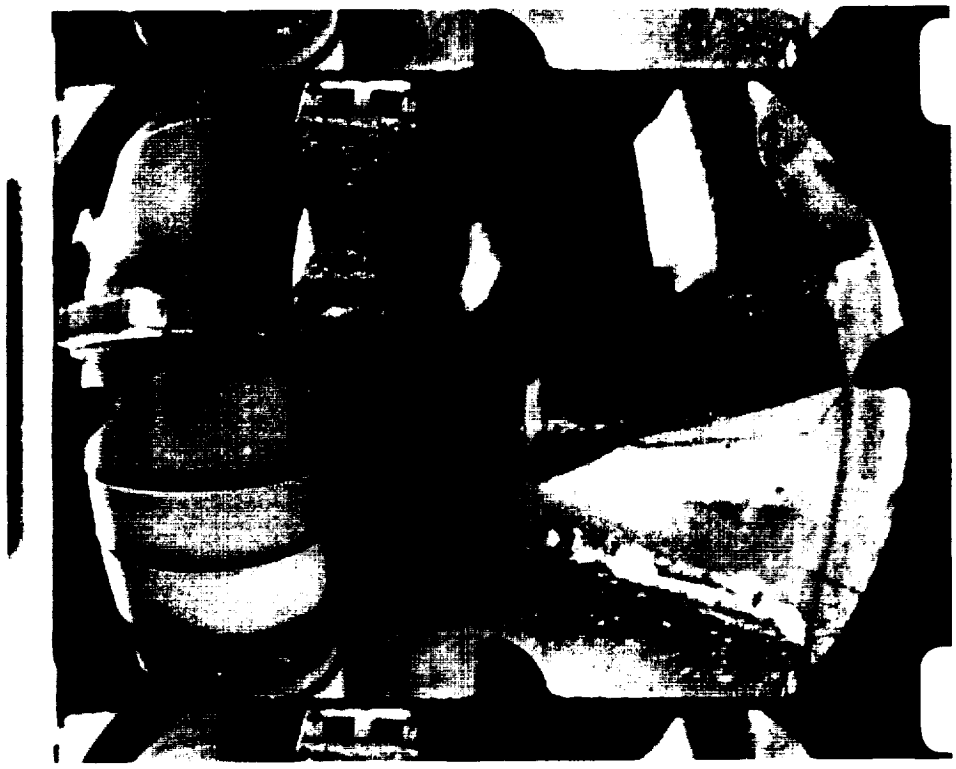


Figure 2.4.2 (A) Dark Debris near Electrical Cable Tray

Three dark pieces of triangular shaped debris were seen to exit from behind the base of the LH2 electrical cable tray and travel in front of the LSRB. The debris did not appear to strike the vehicle.

Figure 2.4.2 (B) Partially Detached TPS

A piece of TPS was seen to partially detach on the left side of the LH2 umbilical. TPS erosion/chipping in the LH2 umbilical area has been seen during previous missions on the umbilical well camera films.

Figure 2.4.2 (C) Separation Bolt Protrudes from the EO-2 Fitting

The separation bolt was seen to protrude from the EO-2 fitting after ET separation. KSC reported that this condition is not considered anomalous. No follow-up action was requested.

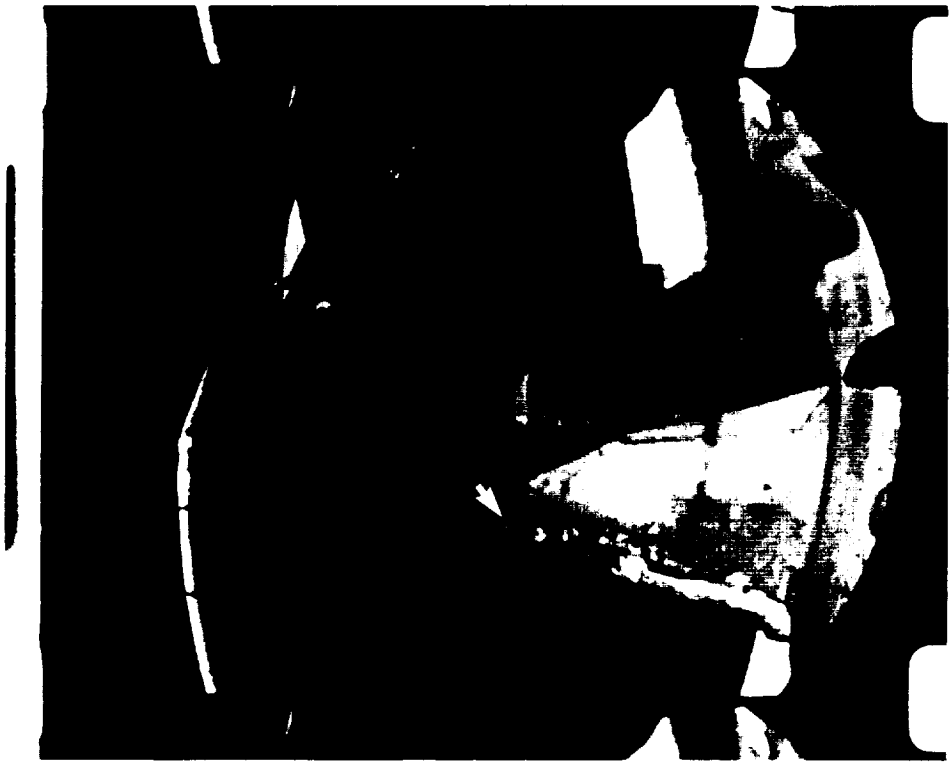


Figure 2.4.2 (D) TPS Detaches from the LH2 Electric Tray

A piece of TPS detached from the base of the LH2 electric tray and traveled away from the vehicle in the -X axis direction. The debris did not appear to strike the vehicle.

2.5 LANDING EVENTS

2.5.1 Landing Sink Rate Analysis (Task #3)

The main gear sink rate of the Orbiter was determined from landing film over a one second time period prior to main gear touchdown. Also, the nose gear sink rate was determined over a one second time period prior to the nose gear touchdown.

The measured main gear and nose gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-74 Orbiter was reported to be 203,000 lb.). The sink rate measurements for STS-74 are given in Table 2.5.1. In Figures 2.5.1 (A) and 2.5.1 (B) the trend of the measured data points for film image data are illustrated.

Prior to Touchdown (1 Second)	Sink Rate: Film
Main Gear	1.5 ft/sec
Nose Gear	4.1 ft/sec

Table 2.5.1 Sink Rate Measurements

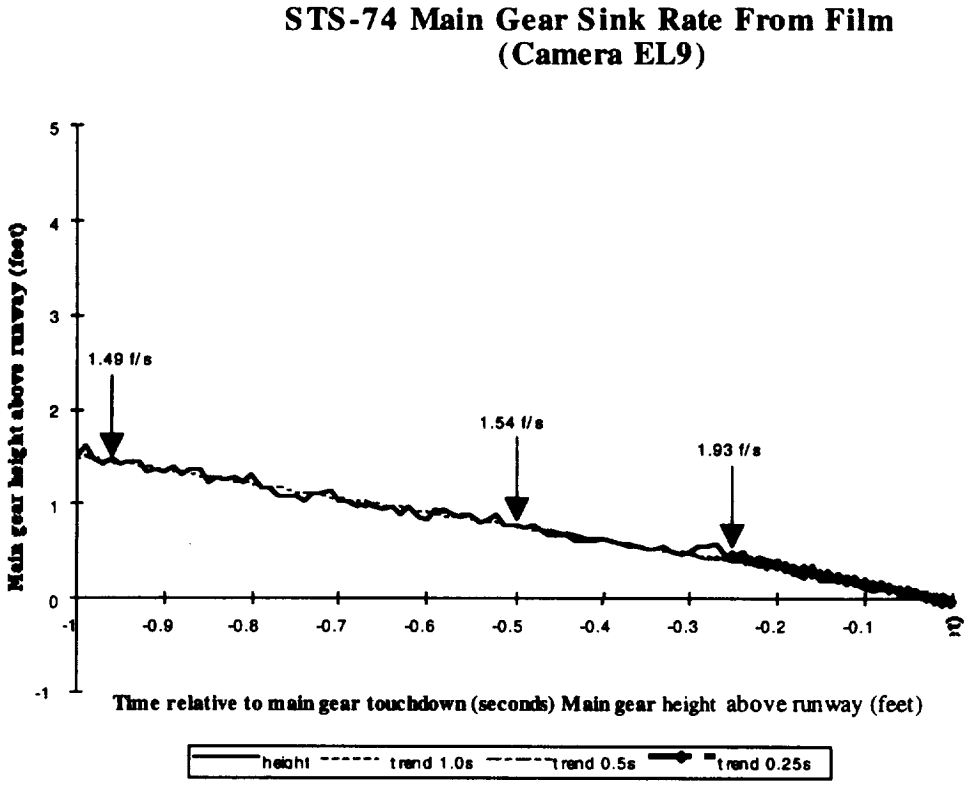


Figure 2.5.1 (A) Main Gear Height versus Time prior to Touchdown (Film)

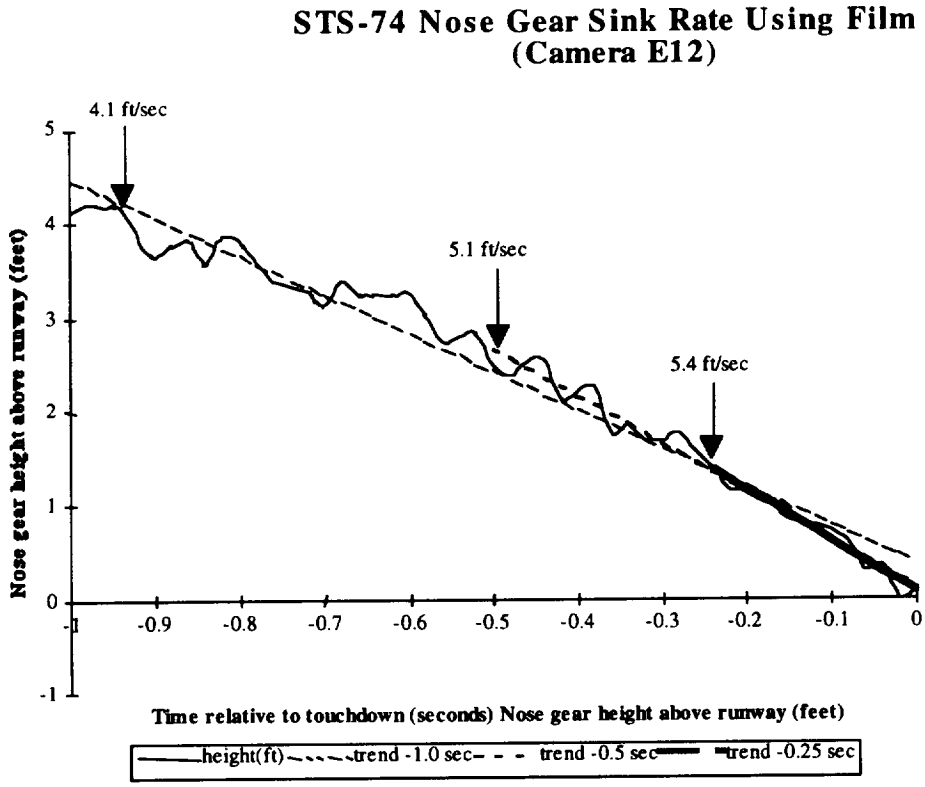


Figure 2.5.1 (B) Nose Gear Height versus Time during Rollout (Film)

2.6 OTHER

2.6.1 Normal Events

Other normal events observed include: inboard elevon motion at SSME ignition, ET twang, acoustic waves in the exhaust cloud at liftoff, vapor off the SRB stiffener rings after liftoff, outgassing of the ET aft dome, roll maneuver, forward RCS paper detaching after the roll maneuver, expansion waves after the roll maneuver, recirculation, SRB plume brightening prior to SRB separation, SRB separation, linear optical effects before and after SRB separation, and multiple pieces of light colored debris in the SRB exhaust plume after separation.

Normal events seen that are related to the pad are hydrogen burn ignitor operation, fixed service structure (FSS) deluge water activation, GH2 vent arm retraction, sound suppression water initiation, mobile launch platform (MLP) water dump activation, and TSM door closure at liftoff.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

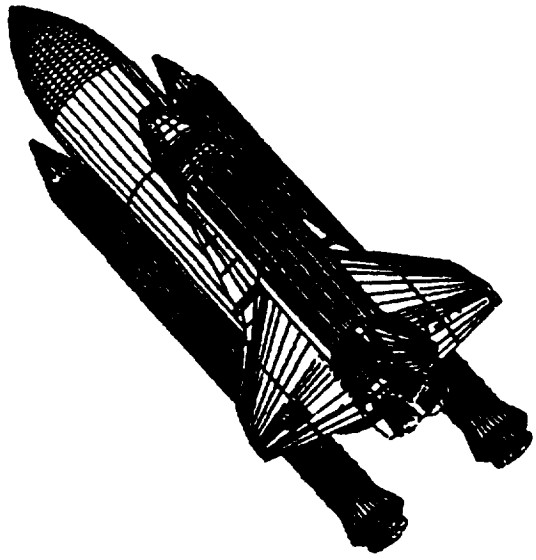
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-74



MSFC - Form 454 (Rev. October 1992)

STS-74 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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December 7, 1995

I. INTRODUCTION

The launch of space shuttle mission STS-74, the fifteenth flight of the Orbiter Atlantis occurred on November 11, 1995, at approximately 6:30 A.M. Central Standard Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage exists and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard the vehicle, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-74 included, but were not limited to the following:

a. Overall facility and shuttle vehicle coverage for anomaly detection
b. Determination of SRB PIC firing time and SRB separation time
c. Verification of Thermal Protection System (TPS) integrity
d. Correct operation of the following:
    1. SSME ingition
    2. SRB debris containment system
    3. LH2 and LO2 17" disconnects
    4. Ground umbilical carrier plate (GUCP)
    5. Free hydrogen ignitors
    6. Booster separation motors (BSM)
    8. Vehicle clearances
    9. Vehicle motion
e. Verification of cameras, lighting and timing systems

III. CAMERA COVERAGE ASSESSMENT:

Film was received from forty-nine of fifty requested cameras as well as video from twenty-five requested cameras. The following table illustrates the camera data received at MSFC for STS-74.

Camera data received at MSFC for STS-74

	16mm	35mm	Video	
MLP	22	0	4	
FSS	7	0	3	
Perimeter	3	3	6	
Tracking	0	14	10	
Onboard	1	1	0	
Totals	33	18	23	
Total number of films and videos received:				74

a. Ground Camera Coverage:

All cameras appeared to operate properly except for tracking camera E-204. A few films were slightly dark in exposure. This is attibuted to the early morning cloud coverage at the launch pad. Ascent coverage was also reduced due to the cloud coverage. The vehicle entered the clouds during the roll maneuver and was visible only during small breaks in the clouds for the remainder of ascent.

b. Onboard Camera Coverage:

The orbiter Atlantis carried two 16mm motion picture cameras in the LH2 umbilical well to record the SRB and ET separation events. The 16mm camera with the narrow field-of-view (10mm lens) failed to operate. A 35mm sequential still camera was flown in the LO2 umbilical well to record the ET after separation.

IV. ANOMALIES:

No anomalies were observed.

V. OBSERVATIONS:

Typical liftoff events such as ice/frost falling from the 17 inch disconnects at SSME start and liftoff, and normal GUCP separation and retraction were observed. Typical events on ascent were observed which include butcher paper debris and flow recirculation.

A bright line was observed on the inside wall of the ME-1 nozzle as shown in Figure one. This bright line is a characteristic of engine 2012 and has been observed on previous mission of engine 2012 (see the MSFC STS-67 Engineering

Photographic Analysis Final Report). This line may be associated with a tube repair on the inside wall of the nozzle.

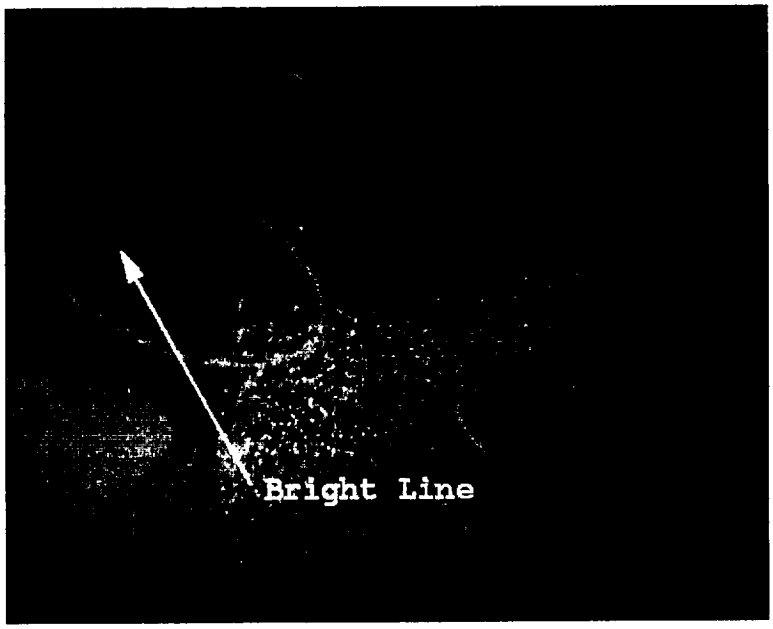

Figure one Bright line in engine 2012 nozzle

A small piece of debris emerges from between the SRB aft skirt and becomes entrained in the SSME plume at T+48.3 seconds as recorded by camera E-223. This event is shown as Figure two. The source of this debris is unknown.

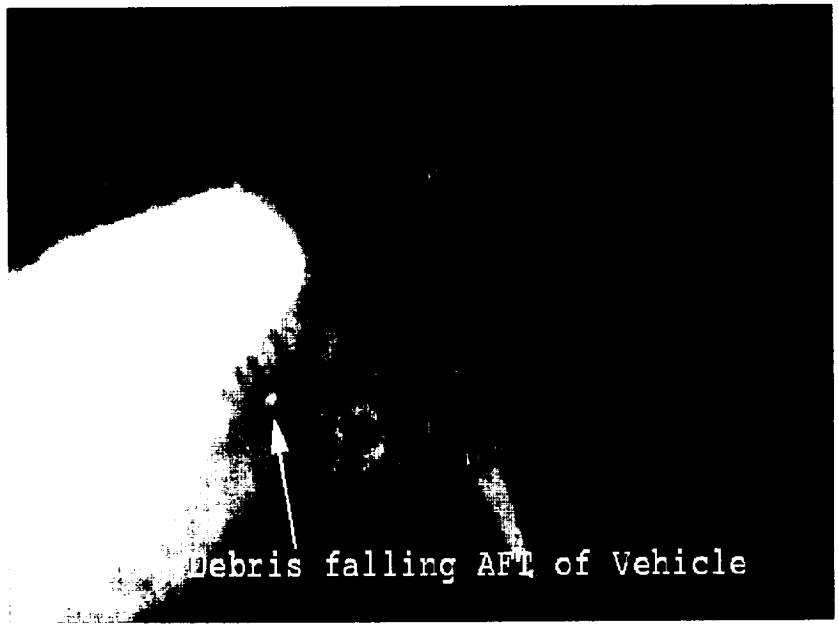

Figure two Debris between aft skirts

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times are determined from cameras that view the SRB holddown posts numbers M-1, M-2, M-5 and M-6. These cameras record the explosive bolt combustion products.

HOLDDOWN POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	12:30:43.021
M-2	E-8	12:30:43.022
M-5	E-12	12:30:43.020
M-6	E-13	12:30:43.021

c. SRB Separation Time:

SRB separation as recorded by the combustion products of the BSMs on film is 316:12:32:46.02 UTC. This time was recorded by camera E-208.

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13. ABSTRACT (Maximum 200 words)

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-74. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanner data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle Mission STS-74 and the resulting effect on the Space Shuttle Program.

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